CHAPTER 14
PACKING, MARKING, STORAGE, AND SHIPMENT OF ENERGETIC MATERIALS

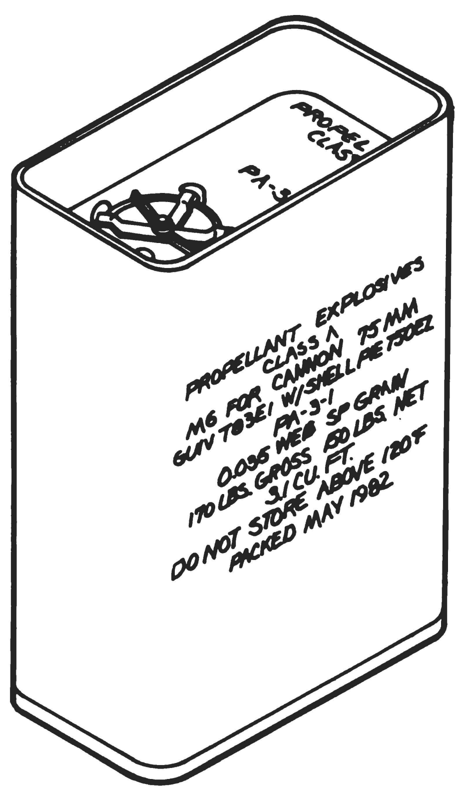
14-1. Introduction. The regulations governing the marking, packing, and shipping of military supplies are set forth in applicable Army regulations. These operations will also comply with Department of Transportation regulations. This chapter contains general regulations applying to the marking, packing, and shipping of explosives and ammunition. No live ammunition component that has been subjected to undue or abnormal forces for test purposes shall be offered for surface shipment by commercial carrier or be transported over public transportation systems by government conveyance except:

a. Items containing small quantities of explosive and constructed or packaged so that their explosive forces will be self-contained if they functior..

b. Explosive items which both the testing agency and the project manager or appropriate major subordinate command agree in writing can be safely transported.

14-2. Packing.

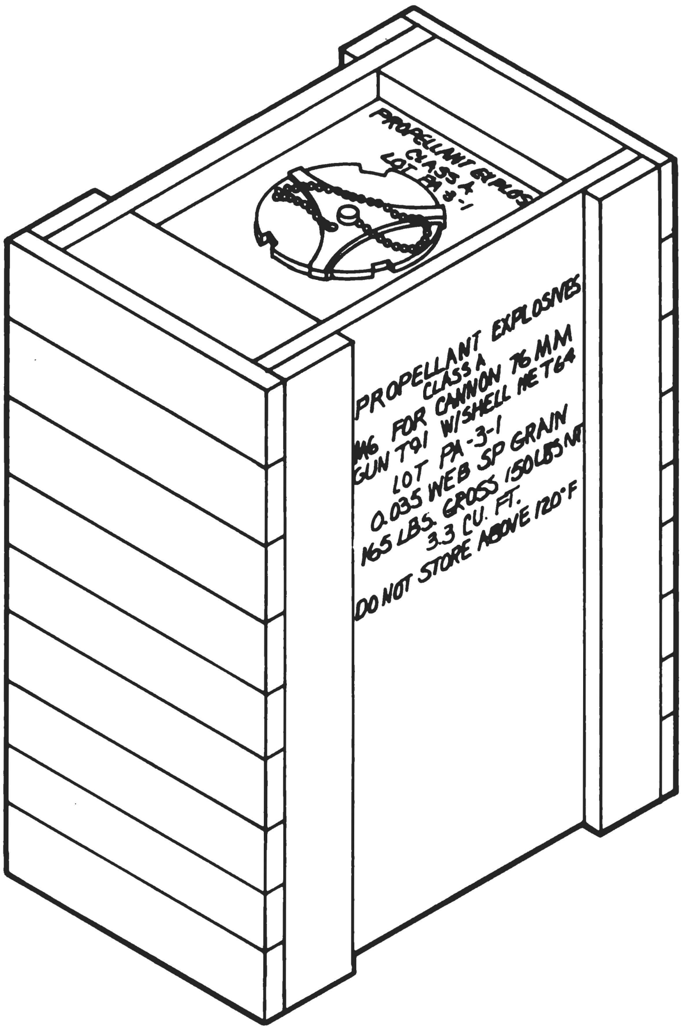
a. *General.* Explosives are packaged to safely meet a wide variety of shipping and storage situations. Storage conditions may vary from the best possible coverage to no cover at all and from extremes in climatic conditions. Figures 14-1 through 14-7 are a representative sample of explosives packaging.



ARR82-0062

Figure 14-1. Steel box for packing solid propellants, including marking.

003731



ARR82-0063

Figure 14-2. Metal lined wood box for packing solid propellants, including markings.

003732

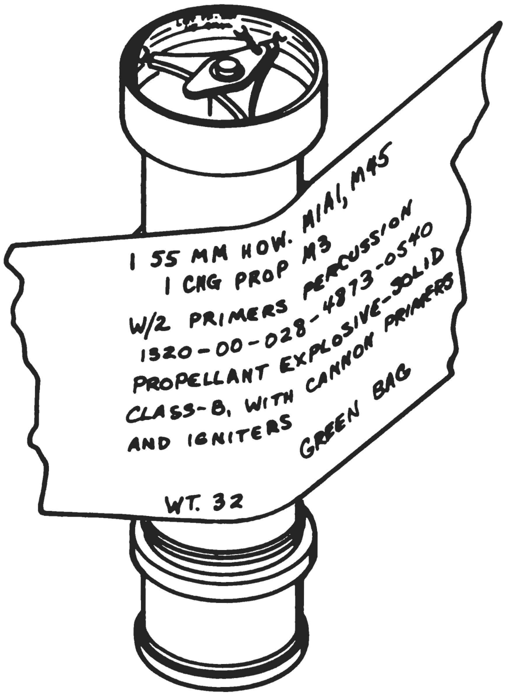
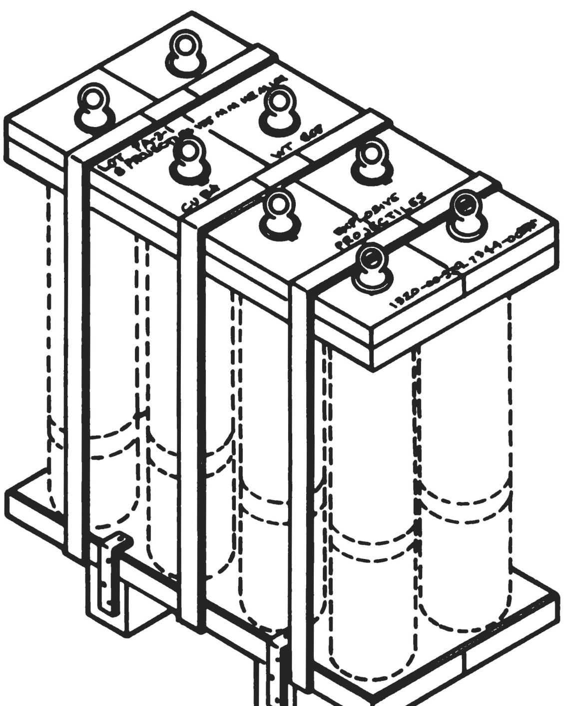
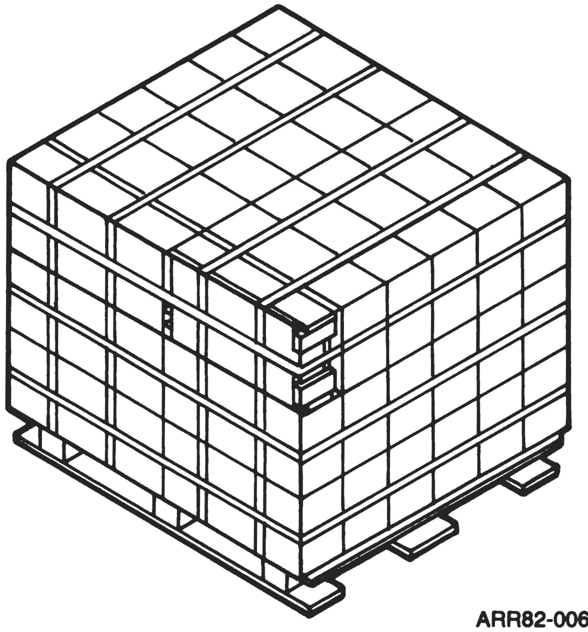


Figure 14-3. Metal containers for propelling charges, including marking.



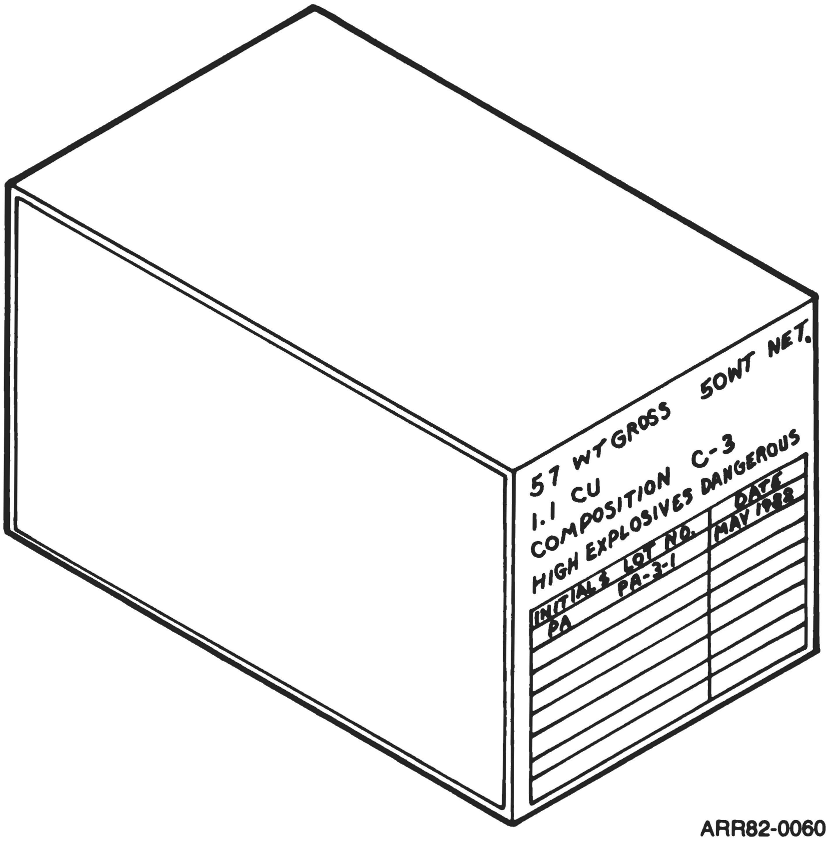
ARR82-0065

Figure 14-4. Palletized large caliber high explosive projectiles, including marking.



ARR82-0066

Figure 14-5. Palletized wood boxes containing explosives.



ARR82-0060

Figure 14-6. Carton for packing high explosives, including marking.

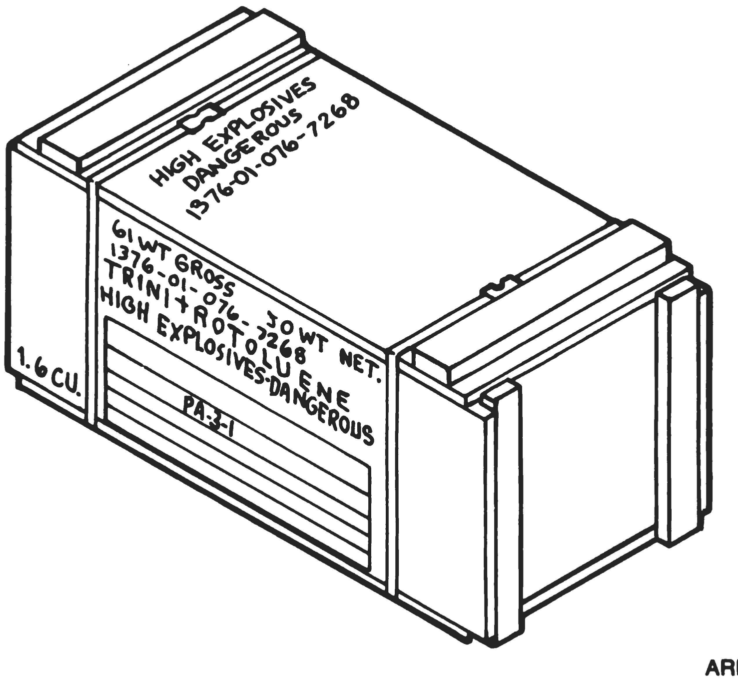


Figure 14-7. Wood box for packing high explosives, including marking.

b. *Containers.*

(1) Hazardous materials in bulk or liquid form must be transported in containers which will prevent leakage. Containers used in intraplant transportation and service storage of explosives and explosives mixtures such as initiating explosives, pyrotechnic compositions, and tracer materials should be made of material in the following order of preference:

(a) Conductive rubber.

(b) Nonferrous metal-lined boxes without seams or rivet heads under which explosive dust can accumulate.

(c) Plastics (conductive type only).

(d) Paper-lined wood boxes.

(e) Fiber drums.

(2) Fiber drums or bulk explosives and propellants should be shipped only by motor carrier or trailer-on-flat car. Glass containers should not be used because of their fragility and severe missile hazard.

c. *Black Powder Containers.*

(1) Standard containers for black powder are built in accordance with drawings that meet DOT specifications.

(2) When black powder is shipped or received each container shall be inspected for holes and weak spots, particularly holes made by small nails which are visible only upon close examination. Damaged containers must not be repaired; the contents shall be transferred to new or serviceable containers.

(3) Empty black powder containers may be reused and may be transported empty provided they are clean. Empty metal containers which are not to be reused and will be salvaged shall be thoroughly washed inside with water.

(4) Black powder containers must be carefully opened. When it is necessary to open containers by puncturing, the operation will be conducted by remote control.

d. *Containers for Solid Propellants.*

(1) Solid propellants shall be packed in accordance with approved DARCOM drawings that comply with DOT regulation (fig 14-1).

(2) Double-based solid propellants, single perforated solid propellants, and all solid propellants with web thickness not greater than 0.4826 millimeters (0.019 inch) should not be packed in all-steel boxes. Metal lined wooden boxes (fig 14-2) should be used.

(3) Salvaged or deteriorated solid propellants should be shipped water wet.

e. *Containers for Ammunition and Bulk High Explosives.*

(1) Ammunition (fig 14-3, 14-4, and 14-5) and bulk high explosives (fig 14-6 and 14-7) shall be packed in accordance with approved DARCOM drawings that comply with DOT regulations.

(2) Containers used for packing bulk high explosives should be lined with strong cloth or paper bags or liners with cemented seams to prevent sifting.

14-3. Marking.

a. Each package of explosives is marked in accordance with pertinent drawings to provide positive identification (NSN, DODAC, nomenclature, lot number, and ICC marking as a minimum).

b. Whenever explosives or ammunition containers or ammunition and ammunition components are repainted, the new painting or marking shall correctly identify contents of items. The marking of empty or inert loaded ammunition items for display purposes is governed by the provisions of AR 385-65.

c. Explosives, ammunition, and loaded ammunition components obtained from salvage operations and material which has lost its identification markings shall be clearly marked to show the explosive nature of the material. Explosive material or items which cannot be definitely identified as to their explosive nature should be disposed of by technically trained personnel in accordance with the provisions of DARCOM-R 385-100.

d. See figures 14-1 through 14-7 for a representative sample of markings required on explosives packaging.

14-4. Storage of Explosives and Ammunition.

a. *General.* The types of existing magazines listed below are considered standard for the storage of the types of items specified. New storage magazines should be of the earth covered, corrugated steel, or reinforced concrete arch type.

b. *Magazines.*

(1) Earth covered magazines. These include igloo, steel arch, Stradley, special type, hillside, and subsurface type magazines. Earth covered magazines are preferred for the storage of all items of ammunition or explosives.

(2) Standard ammunition magazines (commonly called "standard magazines"), classed as above ground magazines. These magazines were designed for the storage of fixed rounds or separate loading projectiles. For future use, they should be restricted to the storage of Classes (04) 1.2, (08) 1.2, (12) 1.2, 1.3, and 1.4 materials (excluding rockets and rocket motors). The magazines measure 15.7 by 66.6 meters (51 feet 7 inches by 218 feet 8 inches), are usually spaced 91.5 meters (300 feet) apart, and have concrete foundation walls and piers, hollow-tile walls, steel frames, and concrete floors. The storage capacity of the magazines is not stated in definite figures since the number of items which can be stored is regulated by the appropriate quantity-distance tables.

(3) High explosives and black powder magazines, classed as above ground magazines. These magazines were designed for the storage of bulk explosives such as black powder, TNT, tetryl, and explosive D and may be used for this purpose where more desirable storage space cannot be obtained. They are 8.4 meters (27 feet 6 inches) wide and 13.2 meters (43 feet 4 inches) long and are usually spaced 243.8 meters (800 feet) apart. They have concrete foundation walls and piers, hollow tile walls filled with sand, steel frames, and concrete floors covered with sparkproof mastic or the equivalent. The magazines were originally designed for the storage of 113,400 kilograms (250,000 pounds) of explosives, but in order to assure adequate aisle space for inspection and shipping and convenient height of piles, the amount of storage is usually limited to approximately 45,360 kilograms (100,000 pounds).

(4) Primer and fuze magazines, classed as above ground magazines. These magazines were designed for storing primers, primer detonators, adapters and boosters, and fuzes of all types. In the future when it is necessary to use magazines of this type, they should be restricted to the storage of Classes (04) 1.2, 1.3 (except rockets and rocket motors), and 1.4 ammunition and explosives. The magazines are 8.4 meters (27 feet 6 inches) wide, 13.2 meters (43 feet 4 inches) long and are usually spaced 91.5 to 121.9 meters (300 to 400 feet) apart. With respect to construction details, they are similar to high explosive and black powder magazines except the hollow tile walls are not sand filled and the floor is not covered with spark proof mastic.

(5) Service magazines and service storage buildings. These buildings are used for intermediate storage of the minimum amount of explosives necessary for safe and efficient manufacturing or processing operations. Construction details of such magazines should specify the use of fire-resistant materials and/or fire-resistive construction.

(6) Other structures. Structures not of approved magazine type shall not be used for the storage of explosives and ammunition except when authorized by the Commander, HQ DARCOM, Attn: DRCSF.

c. *Temperature Control.*

(1) Sudden changes in temperature may damage airtight containers or may result in excessive condensation of moisture. If the temperature in a magazine exceeds 37.8°C (100°F) for a period of more than 24 hours, the magazine should be cooled by wetting the exterior of the building with water or by opening the doors and ventilators after sunset and closing them in the morning. If these methods do not prove effective in lowering the temperature, the Commander shall decide whether the materials should be removed to some other magazine.

(2) Storage magazines, in general, should not be provided with heat. Exception is made in the case of magazines where heating may be necessary to prevent condensation of moisture, to maintain constant temperature, or other reasons. If steam or hot water coils are used to heat a magazine, they must be so arranged that explosives material cannot come in contact with the coils. The coils must be kept clean.

d. *Magazine Operational Regulations.* The following regulations shall be complied with where ammunition and explosives are stored:

(1) Instructions as printed on magazine placards, DA Label 85, must be posted on or near each door of the magazine so that they are visible when work is being done in the magazine.

(2) Loose components of ammunition, packing materials, conveyors, skids, dunnage, empty boxes, and other similar material shall not be stored in magazines containing ammunition or explosives.

(3) Vegetation around all ammunition and explosives storage locations shall be controlled.

(4) Doors and locks must be kept in good working order. Magazines shall be locked at all times except when permitted operations are in progress in the magazine and as provided for in paragraph 14-4c(1). A crew must not be permitted to work in a position in a magazine which requires passing the work aisle or position of a second crew to reach an exit. The number of crews shall not exceed the number of exits. Two or more doors must be unlocked and open when personnel work in magazines having more than one door.

(5) Flammable liquids, except when used as the chemical filler of a munition or as a prepackaged storable liquid propellant, shall not be stored in magazines containing explosives.

(6) Except when required for security purposes, service magazines within an operating line need not be locked during shift operations. These magazines must be locked whenever the operating line is shut down; i.e., nights, weekends, and holidays.

e. *Stacking.*

(1) Ammunition and explosives shall be stored in containers as prescribed by approved DARCOM drawings and specifications and shall be stacked and arranged in a magazine in accordance with instructions set forth in Army regulations and approved DARCOM drawings and directives. Explosives or ammunition in stacks shall be grouped and identified according to lots. When military explosives or ammunition are not packed in accordance with approved drawings and specifications, they must be stored in accordance with special instructions from the Commander DARCOM, ATTN: DRCSF. General rules set forth in paragraphs (2) and (3) below should be followed in the absence of applicable storage drawings.

(2) Methods used for stacking must provide for good ventilation to all parts of the stack. Adequate dunnage shall be used for this purpose.

(3) Aisles shall be maintained so that units in each stack may be inspected, inventoried, and removed for shipment or surveillance tests. Block storage is permitted, provided adequate ventilation of stacks exists. Unobstructed aisles shall be maintained to permit rapid egress of personnel.

(4) Only one light box, pallet, or unit should be allowed per lot in storage. A light box, pallet, or unit is defined as a box, pallet, or unit which contains less than the normal quantity or count. Packaging and marking shall be in accordance with approved drawings and regulations. Light units shall be readily visible and immediately accessible when stacked in storage. Light units might be painted white.

f. *Permitted Open Storage.*

(1) Open storage of ammunition/explosives and limited material will not be used in lieu of covered storage employing standard facilities and/or methods.

(2) When circumstances dictate that open storage must be utilized for storage of Army owned material, the storing installation will submit a request for waiver in accordance with DARCOM-R 385-100. Requests involving material owned by another service will be forwarded through the same channel (through HQ DARCOM, ATTN: DRCSF-E) to the owning service.

(3) Bulk solid propellants, bagged propelling charges, pyrotechnics, bulk high explosives, and critical items shall not be placed in open storage.

g. *Open Storage Sites.*

(1) Sites for open storage shall be separated from magazines, other facilities, and each other in accordance with the requirements of Chapter 12.

(2) The storage sites shall be level, well drained, and free from readily ignitable and flammable materials. The supporting timbers or platform upon which the ammunition is stored shall be well constructed to prevent falling, sagging, and shifting of the ammunition. In order to assure stack stability and free circulation of air, not less than three inches of dunnage should be used between the bottom of the stack and the earth floor. Provisions should also be made for circulation of air through stacks. Non-flammable or fire-resistant, waterproof, overhead covers should be provided for all ammunition containing solid propellants, torpex, tritonal, minol, or chemical agents since each of these materials may be adversely affected by exposure to the elements. An air space of not less than .45 meter (18 inches) should be maintained between the top of the stack and the cover. If adequate ventilation is assured, overhead covers are also desirable for outdoor stacks of bombs and shells. Sides of covered stacks also may be protected by non-flammable or fire-resistant, waterproof covers provided air space is maintained between the cover and the ammunition.

(3) Frequent inspections shall be made to detect sagging piles and accumulations of trash between or under stacks.

(4) If revetments are to be provided around open storage sites, they must comply with the requirements of Chapter 12. Stacks of ammunition must be kept at least 0.61 meter (two feet) from the base of the revetment and at least 0.31 meter (one foot) below the top of the revetment.

(5) Excess dunnage should not be stored between open sites and magazines nor between magazines. Excess dunnage storage sites should comply with applicable quantity-distance requirements except that during open storage operations, service supplies of dunnage may be located not closer than 15.3 meters (50 feet) from the stack being processed.

(6) Suitable types of firefighting equipment and fire symbols should be provided.

h. *Special Requirements for Open Storage.*

(1) Sites between earth covered magazines. Sites may be located midway between adjacent earth covered magazines which are 121.9 meters (400 feet) apart, provided the sites are barricaded and are separated from the barricaded sides of the nearest magazine by 56.4 meters (185 feet). Ammunition in such sites should not be stored beyond lines drawn through the fronts and backs of magazines in the same row. Barricading does not reduce the required inhabited building or public traffic route distances. The storage of Class 1.2 between earth covered magazines is not desirable and should be resorted to only when necessary. Sites containing Class 1.2 may not be located closer than the fragment distance from other open sites. The limitations of the quantity-distances listed in table 14-1 also are applicable.

Table 14-1. Special Requirements for Open Storage Between Earth Cover Magazines

Hazard class and division		Maximum kilograms (pounds) of HE		Minimum intersite distance meters (feet)		
	1.4		No limit	121.9	(400)	
(04)	1.2	45,360	(100,000)	121.9	(400)	
(08)	1.2	45,360	(100,000)	243.8	(800)	
(12)	1.2	45,360	(100,000)	365.7	(1,200)	
(18)	1.2	45,360	(100,000)	548.6	(1,800)	
	1.1	45,360	(100,000)	121.9	(400)	or fragment distance (if appropriate) whichever is greater.

(2) Sites not between earth covered magazines. Sites containing Class 1.2 shall not be stored closer than fragment distance from other sites. No open storage site shall be located within 365.7 meters (1,200 feet) of above ground magazines. The limitations of the quantity-distances listed in table 14-2 also are applicable.

Table 14-2. Special Requirements for Open Storage Between Magazines That Are Not Earth Covered

Hazard class and division		Maximum kilograms (pounds) of HE		Minimum intersite distance meters (feet)			
	1.4		No limit	30.5	(100)		
(04)	1.2		No limit	121.9	(400)		
(08)	1.2	226,800	(500,000)	243.8	(800)		
(12)	1.2	226,800	(500,000)	365.7	(1,200)		
(18)	1.2	45,360	(100,000)	548.6	(1,800)		
	1.1	45,360	(100,000)	85.3	(280)	(barricaded)	or fragment
		45,360	(100,000)	155.4	(510)	(unbarricaded)	distance (if
		113,400	(250,000)	115.8	(380)	(barricaded)	appropriate)
		113,400	(250,000)	211.8	(695)	(unbarricaded)	whichever
							is greater

(3) General. Inhabited building distance and public traffic route distance shall be maintained around open storage sites as specified in Chapter 12.

i. *Storage of Bulk Initiating Explosives.* Bulk initiating explosives must not be stored dry and shall not be exposed to the direct rays of the sun. Glazed earthenware crocks of ample size to hold the double bag of material with covers of the plastic cap type to prevent evaporation and eliminate friction or abrasion when removed are used for normal storage. Proper selection and use of covers is required to prevent friction and pinch points. If long term storage in shipping containers is contemplated, the container must be equipped with a cover having a port for observation of the level of liquid therein. The viewing port must be covered with a transparent plastic which is known to be compatible with the initiating explosives being stored. As an expedient only, bulk initiating explosives may be stored in shipping containers that are not so equipped, provided they are stored in frostproof, earth covered magazines, with containers on end, only one tier high, and with passageways for inspection and handling. Bags of initiating explosives in storage containers must be under distilled water. Alcohol may be added to the distilled water to prevent freezing.

j. *Solid Propellants.* Propellants shall not be stored or shipped in damaged containers. When leaking containers are discovered, an examination of the contents shall be made for the nitrous odor of decomposing propellant. If any such condition is observed, the propellant shall be segregated or properly disposed of. Propellants and propelling charges in containers should be stored so that they can be readily inspected. They shall not be exposed to the direct rays of the sun.

k. *Small Arms Ammunition.* Boxed small arms ammunition shall not be used as barricades or dividing walls between stacks of other types of ammunition.

l. *Separate-Loading Ammunition, HE Loaded Except Explosive D.*

(1) Separate-loading projectiles must be handled with care. They shall not be stored without fuze-well closing plugs. Metal dunnage should be used where practicable.

(2) Class (18) 1.2 quantity-distances are the minimum acceptable for Class (18) 1.2 items, regardless of the quantities of the HE involved. For Class (18) 1.2 separate-loading projectiles, storage must comply with DARCOM Drawing 19-48-4102-1-2-14PE1001 in order to limit distance requirements to those prescribed by the Class (18) 1.2 quantity-distance table. If those projectiles are equipped with core-recessed lifting plugs, the Class 1.1 quantity-distance table applies when the total quantity of HE involved exceeds 6,804 kilograms (15,000 pounds) in above ground magazines, even if storage complies with DARCOM Drawing 19-48-4102-1-2-14PE1001.

m. *Separate-Loading Ammunition Explosive D Loaded, Class (12) 1.2.* Except where permanent block type storage methods are used, this type of projectile may be stored with distances between stacks not more than that required to permit inspections.

n. *Fixed and Semi-Fixed Ammunition.* Boxed fixed and semi-fixed ammunition shall not be used as barricades or dividing walls between stacks of other types of ammunition.

o. *Rockets and Rocket Motors.*

(1) Whenever practicable, rockets and rocket motors that are in a propulsive state should be stored nose down. Small rockets and missiles may be stored in standard earth covered magazines without regard to direction in which they are pointed except that they will not be pointed toward the door of the magazine. If not in a propulsive state, any rocket, rocket motor, or missile may be stored in any magazine without regard to the direction in which they are pointed.

(2) In above ground magazines where nose down storage is not practicable, items (in a propulsive state) shall be pointed in the direction which offers the least exposure to personnel and property in the event of fire or explosion.

(3) Rockets should be stored in a dry, cool magazine out of the direct rays of the sun. They should not be stored in locations where temperatures exceed 49°C (120°F). Prolonged exposure of rocket ammunition to either high or low temperatures may increase the normal rate of deterioration or render the motors more susceptible to ignition if subsequently handled improperly.

14-5. Shipment of Explosives and Ammunition.

a. *General.* Explosives and ammunition are routinely shipped via all common modes of transportation, i.e., railroad, truck, ships, and aircraft. However, due to the commodities hazardous nature each of the transportation modes rigidly adheres to its own specific set of regulations.

b. *Railroad Transportation.* The operation of railroads within a DARCOM establishment shall be in accordance with applicable current directives, particularly TM 55-200, Railroad Operating Rules and this regulation.

(1) Specifications for equipment. The regulations of the Department of Transportation, the Federal Railroad Administration, and the Association of American Railroads pertaining to safety devices, safety guards, design of equipment, etc. are mandatory for railway equipment involved in transporting materials between establishments. The same regulations should be followed for inspection, maintenance, and operation of railroad equipment within an installation.

(2) Transportation of hazardous materials.

(a) In addition to the requirements of other parts of this section, the rules in subparagraphs (b) through (i) below shall be followed.

(b) When cars containing explosives or other hazardous materials are received at the installation or held in yards, precautions must be taken to prevent accidents, particularly at night. These precautions must include provisions for quickly removing and isolating the cars in case of fire.

(c) Cars loaded with hazardous materials must be loaded and placarded as prescribed by Department of Transportation regulations before being offered for transportation. The carrying of hazardous materials on locomotives or other self-propelled rail vehicles is prohibited.

(d) Before cars are moved by a locomotive, the air brake hose must be coupled and tested to assure that the air brakes are in proper working condition and the car doors shall be closed.

(e) Empty cars shall not be removed from warehouses, magazines, buildings, or loading docks until all warning placards have been removed.

(f) Special care must be taken to avoid rough handling of cars. Cars must not be "cut off" while in motion and must be coupled carefully to avoid unnecessary shocks. Other cars must not be "cut off" and allowed to strike a car containing explosives. Cars must be so placed in yards or on sidings that they will be subject to a minimum of handling and be readily removed from danger of fire. Such cars must not be placed under bridges or in or alongside passenger sheds of station, and where avoidable, engines on parallel tracks should not be allowed to stand opposite or near them.

(g) "Dropping," "humping," "kicking," or the use of the flying switch is prohibited.

(h) Adequate measures such as guarding, patrolling, and safety inspection must be provided at all times. All such activity should be under positive administrative controls.

(i) Fire symbols or DOT placards shall be placed on each railroad car while transporting explosives or ammunition within a DARCOM establishment in order to provide a ready means of identifying the potential hazard should a fire occur.

(3) Placarded railcars. Placards shall be applied in accordance with DOT regulations to railcars transporting hazardous materials. Ammunition and explosives shall be loaded and braced in accordance with approved drawings.

(4) Car inspection. A car must not be loaded with any DOT Class A explosives unless it has been thoroughly inspected by a qualified employee of the carrier who shall certify that its condition conforms to DOT regulations. After a certified car has been furnished by the carrier, the shipper or his authorized employee must, before commencing the loading of any such car, inspect the interior thereof and after loading, certify to its proper condition. A certificate will be completed and signed where applicable. Shipments of Class B explosives may be loaded in a closed car or container car which is in good condition, into which sparks cannot enter, and with roof not in danger of taking fire through unprotected decayed wood. Wood floored cars must be equipped with spark shields. Such cars do not require a car certificate but must be placarded in accordance with paragraph 14-5b(3) above.

(5) Car certificates. The car certificate printed on strong tag board measuring 177.8 millimeters × 177.8 millimeters (7 by 7 inches) or 152.4 by 203.2 millimeters (6 by 8 inches) must be duly executed in triplicate. The original copy must be filed by the carrier at the forwarding station in a separate file and the other two must be attached to the car, one to each outer side on a fixed placard board or as otherwise provided.

(6) Leaking packages. Constant alertness must be maintained to detect, through characteristic odors, the leakage of hazardous materials from faulty packages. Leaking packages should be removed from cases and repaired, or if in tank cars, the contents should be transferred. If artificial light is necessary, only electric lights approved for the hazard involved shall be used. Leaking tank cars containing compressed gases shall be switched to a location distant from habitation and highways and proper action taken for transferring contents under competent supervision. Cars containing leaking packages or leaking tank cars must be protected to prevent ignition of liquid or vapors by flame from inspectors' lanterns or torches, burning fuses, switch lights, switch thawing flames, fires on side of track, or from other sources. All unnecessary movement of a leaking car discovered in transit must cease until the unsafe condition is remedied.

(7) Car loading of items containing ammunition and explosives. Loading methods prescribed by DARCOM drawings shall be followed for the loading and bracing of railway car shipments of military explosives and ammunition. The packages should be placed in position with no more force than is needed to secure a compact load and to prevent shifting and damage en route. Excessive or violent use of mauls shall not be permitted when positioning packages.

(8) Sealing cars containing explosives and ammunition. In addition to any other seals which may be used, cars containing explosives or ammunition shall be sealed. A cable seal lock will be used to secure car doors plus an upper rail lock. Serial numbers of seals will be placed on GBL (DOD 5100.76M and AR 55-355, Chapter 13). If the seal is not in place when the car is received, the car shall be treated as suspicious and shall be inspected. See AR 55-38 for instructions on recording details when shortage, pilferage, or apparent theft is involved.

(9) Inspection of cars before unloading.

(a) Rail cars containing explosives and ammunition entering a DARCOM establishment must be inspected. This inspection comprises the examination of the outside and under side of each car for damage such as defective brakes, couplings, wheel flanges, etc; to detect unauthorized and suspicious articles; to check correctness of individual car numbers and seal numbers against bills of lading. When the probability of sabotage is remote, such inspections may be accomplished from ground level without the aid of an inspection pit to discover unsafe structural and mechanical deficiencies of the car. During periods of emergency when sabotage may be attempted, and also to aid in the rapid inspection and movement of cars, an inspection pit should be provided.

(b) Cars of ammunition or explosives on which foreign and suspicious articles have been secreted or attached outside or underneath the car, or cars which show a defect that might affect the installation or contents of the car, shall be removed to the suspect car siding for additional inspection. In addition, during the times of national emergency, cars on which the seal numbers do not correspond to those shown on the bill of lading shall be treated as suspect cars and should be removed to the suspect car siding for additional inspection.

(c) Cars which satisfactorily pass the inspection outlined above may be considered reasonably safe but care must be exercised in breaking car seals and opening car doors because of the possibility of damage or shifting lading, leaking containers, etc. When the quantity and class of ammunition present in the classification yard does not exceed that permitted by the appropriate quantity-distance table, based on distance to adjacent targets, cars may be opened for inspection at that point, otherwise interior inspection should be accomplished after the cars have been spotted at the unloading point.

(10) Inspection of cars after unloading. Cars in which explosives or ammunition are received shall be inspected after unloading to see that they are clean and free from loose explosives or other flammable materials, and that the placards and car certificates are removed. Explosives sweepings shall be destroyed.

(11) Damaged shipment. Any shipment received in a damaged condition as a result of inadequate or improper blocking and bracing or not loaded in accordance with appropriate DARCOM drawings shall be reported on Discrepancy Shipment Report (SF 361) in accordance with AR 55-38. If the damage was due to improper preservation, packaging, or packing, SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

c. *Motor Vehicle Transportation.* The operation of motor vehicles within a DARCOM installation shall be in accordance with this and other applicable current regulations.

(1) Motor vehicle safety program. Current regulations, particularly AR 385-10, Army Safety Program, require the institution of a motor vehicle safety program as part of the overall safety program of a DARCOM installation. AR 385-55, Prevention of Army Motor Vehicle Accidents, contains detailed information for inclusion in such a program. Other pertinent regulations are AR 55-162, AR 55-203, AR 55-355, AR 55-357, AR 735-11-2, and AR 55-38.

(2) Motor vehicle shipment regulations. Motor vehicle shipments on public highways are governed by the Department of Transportation regulations. All motor vehicle shipments from a DARCOM installation shall comply in full with the applicable portions of DOT, state, and municipal regulations except as provided for in these regulations. Before any motor vehicle designated for movement over public highways may be loaded with ammunition or explosives (DOT Class A or B) and other dangerous articles, as specified in chapter 216, Section II, AR 55-355, the vehicle must be inspected and approved by a qualified inspector for compliance with AR 55-355 (DD Form 626) Motor Vehicle Inspection. After loading, lading must be inspected and approved. Driver selection, training, etc., for intraplant shipping and for operation of government owned trucks on public highways shall be in accordance with pertinent requirements of 49 C.F.R. Parts 390-397, Federal Motor Carrier Safety Regulations, FM 55-30, Army Transportation, Units and Operations, and FM 21-305, Manual for the Wheeled Vehicle Driver.

(3) Motor vehicle for explosives shipment. Cargo type trucks and truck-tractor drawn semitrailer vans are the preferred means for transporting ammunition, explosives, and other hazardous material. Other types of trailers should not be used by DARCOM installations for this purpose except where the material is sufficiently large to make handling by vans impractical (this restriction need not apply to licensed common carriers and contract equipment). Equipment used for transporting ammunition, explosives, and other hazardous material must meet the following requirements and these should be supplemented by local regulations as deemed necessary by the commander.

(a) Loading methods prescribed by DARCOM drawings shall be followed for the loading and bracing of motor vehicle shipments of military explosives and ammunition. The packages should be placed in position with no more force than is needed to secure a compact load and to prevent shifting and damage en route. Excessive or violent use of mauls shall not be permitted when positioning packages.

(b) Special precautions must be taken to avoid ignition of the material by the exhausts of automotive vehicles.

(c) The lighting system shall be electric. Batteries and wiring shall be so located that they will not come into contact with containers of explosives, ammunition, or other hazardous material. If exposed explosives or flammable vapors are encountered in a vehicle, only approved type portable lights should be permitted (certified by a nationally recognized testing organization for the specific hazardous location as defined by the National Electric Code).

(d) The interior of the truck body shall have all exposed ferrous metal covered with nonsparking material when transporting scrap and bulk explosives in containers which may be damaged and explosives become exposed. If the explosives transported consist of ammunition or explosives packaged for shipment in accordance with DOT specifications, it will not be necessary to cover the ferrous metal. Open body vehicles other than the flatbed trailer type used to transport large items such as rockets or missiles must have sides that are strongly made and securely fastened so that the items are safely retained. Where a top is required, it should be of a noncombustible or flame-proof material. Whenever tarpaulins are used for covering explosives, they will be secured by means of rope or tiedowns. Nails will not be used to fasten protective tarpaulins.

(e) All trucks (government and commercial) destined for offpost shipment over public highways shall be equipped with one (1) Class 10-BC rated portable fire extinguisher when transporting DOT Class A, B, or C explosives. Government motor vehicles involved only in on-post shipments shall be equipped, as a minimum, with two (2) Class 1-BC rated portable fire extinguishers; one mounted outside the cab on the driver's side of the vehicle and the other inside the cab. If government vehicles are equipped with an interior carbon dioxide or dry powder flooding device, only one extinguisher is required and should be mounted on the outside of the cab on the driver's side.

(f) Red lights are not permitted on the front of vehicles transporting explosives and ammunition.

(g) Trucks fueled with LP gas shall not be used to transport ammunition and explosives in ammunition areas.

(4) Inspection of vehicles. Government owned motor vehicles used for transportation of hazardous materials shall be inspected at frequent intervals by a competent person to see that mechanical condition and safety devices are in good working order and that oil and motor pans under engines are clean. Because of vehicle usage, this requirement is over and above the inspection requirements of TM 38-750. Daily inspection shall be made by operators to determine that:

(a) Fire extinguishers are serviceable.

(b) Electric wiring is in good condition and properly attached.

(c) Fuel tank and piping are secure and not leaking.

(d) Brakes, steering, and other equipment are in good condition.

(e) The exhaust system is not exposed to accumulations of grease, oil, gasoline, or other fuels, and has ample clearance from fuel lines and other combustible materials.

(5) Mixed loading. The types of hazardous materials that may be loaded and transported together over public highways are established in 49 CFR 177.835(c) and 177.848. These DOT requirements shall be complied with for shipments over public highways.

(6) Instruction to drivers. Before motor vehicles loaded with hazardous materials leave a DARCOM establishment, drivers shall be informed of the nature of their cargo and methods of fighting fires involving the truck or its cargo. DD Form 836 (Special Instructions for Motor Vehicle Drivers) will be completed in accordance with the requirements of AR 55-355 and furnished such drivers. The provisions of TB 38572, Nuclear Weapons - Fire Fighting Procedures, shall be applied, when applicable.

(7) Inspection and movement of incoming shipments.

(a) Motor vehicles loaded with explosives, ammunition, or other hazardous materiel shall be carefully inspected by a competent person at a designated inspection station in accordance with AR 55-355 using DD Form 626. The inspection station should be located remotely from hazardous and populated areas.

(b) When inspection reveals that an incoming tractor is in an unsatisfactory condition, it should be disconnected from the trailer (at the inspection station) and moved to a position where it will not endanger any explosives.

(c) When inspection reveals that the trailer or its load is in an unsatisfactory condition, it shall be removed to a location which is at least inhabited building distance (not less than fragment distance for fragment producing items) for the material involved from inert and administration areas, hazardous locations, and the installation boundary. At this location, correction of unsatisfactory conditions shall be accomplished prior to movement to the destination of the vehicle within the installation. The route when moving from the inspection station to the isolated locations, insofar as possible, should be removed from built-up areas and areas where personnel concentrations are high.

(d) Vehicles which cannot be dispatched immediately to points where they are to be unloaded may be moved to a holding yard which shall be sited in accordance with paragraph 12-11l.

(e) Incoming or outgoing ammunition and explosives loaded trailers that cannot be exchanged directly between the carrier and the DARCOM installation may be moved in to interchange yard. Quantity-distance provisions do not apply provided the trailers are moved expeditiously from the interchange yard. At least 3.048 meters (10 feet) separation should be maintained between trailers in an interchange yard.

(8) Damaged shipments. Any shipments received in a damaged condition as a result of inadequate or improper blocking and bracing or not being loaded in accordance with appropriate DARCOM drawings shall be reported on Discrepancy Shipment Report (SF 361) in accordance with AR 55-38. If the damage was due to improper preservation, packaging, or packing SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

d. *Air Transportation.* The carriage of ammunition, explosives, and other hazardous materials by civil aircraft is regulated by the DOT. See 49 CFR 106-178, particularly Part 175. Criteria for the preparation and carriage of hazardous materials on military aircraft and certain Department of Defense contract airlift operations conducted under DOT Exemption 7573 are contained in TM 38-250.

(1) Military aircraft operating regulations.

(a) Operation of military aircraft shall be in accordance with requirements outlined in the applicable flight envelope, Army and/or Air Force regulations, and as further required by locally established regulations.

(b) If an aircraft carrying dangerous articles makes a forced landing and only minor repairs are necessary, the cargo need not be unloaded but repairs should be accomplished at a location separated from dissimilar exposures and other aircraft by the appropriate inhabited building distance for the cargo aboard. For major repairs, the plane shall be unloaded and the cargo stored in accordance with appropriate quantity-distance requirements. Appropriate protection should be afforded the cargo during inclement weather. If a landing is made for refueling purposes only, the cargo need not be unloaded. Refueling shall be accomplished at a location suitable for the performance of minor repairs as described above.

(c) Prior to take off or landing, the pilot must contact the tower for taxi, take off, or landing and parking instructions. The pilot shall, when requesting instructions, make known the contents of the cargo and shall request priority for his aircraft.

(d) When an aircraft containing ammunition or explosives is parked on a DARCOM installation in a designated, restricted, posted, and traffic controlled explosives parking or loading and unloading area, fire symbols will be posted at all normal approaches to the designated area. If parked in an area on a DARCOM installation which is not a designated, restricted, posted, and traffic controlled explosives parking or loading and unloading area, fire symbols will be placed at the nose, tail, and each side of the aircraft. Where the height of the aircraft does not readily permit attaching the fire symbols to the aircraft, the fire symbols may be mounted on stands approximately 1.5 meters (five feet) in height positioned adjacent to the aircraft where they are visible at long range. At other DOD installations and at non-DOD installations, placarding will be in accordance with the requirements of TM 38-250 and the requirements of the host installation.

(2) Permissible air shipments. Hazardous materials that may be shipped by civil air are identified in 49 CFR 172.101 along with the maximum net quantities per package and in Chapter 4 of TM 38-250 for shipments by military aircraft. External or internal transportation of electrically initiated explosive loaded items or components by helicopter will not be permitted without prior approval from the Commander, DARCOM. Packages must conform to the requirements of DOT regulations. Dangerous articles and other cargo must be firmly lashed to the aircraft structure or otherwise secured to prevent shifting in flight. Signalling devices, equipment necessary to promote safety in operations, small arms equipment in moderate quantities for personal use, and other items as permitted in Title 49 CFR part 175.10 may be carried without complying with the above requirements. Dangerous articles must be placed in a baggage compartment inaccessible to passengers during flight.

(3) Loading and unloading aircraft.

(a) Prior to loading or unloading ammunition, explosives, and other hazardous materials, the aircraft shall be electrically grounded so that the resistance to ground does not exceed 10,000 ohms.

(b) When loading or unloading aircraft containing ammunition or explosives, placards and fire symbols will be displayed as indicated in paragraph 14-5d(1)(d).

(c) Loading and unloading shall be done in accordance with quantity-distance requirements (para 14-5d(1)(b).

(d) All ignition switches must be in the off position.

(e) Front and rear wheel chocks shall be in place.

(f) Military aircraft shall be loaded in accordance with AR 95-16, "Weight and Balance: Army Aircraft". Nonmilitary aircraft shall be loaded to comply with Civil Air Regulations.

(g) Nonmilitary airfields used for loading and unloading explosives will be provided with aircraft firefighting service equal to Army standards.

(h) At nonmilitary airfields used by US Army Flight Activities, aircraft rescue and fire protection is normally provided by the host. If protection provided by the host does not meet the standards established in AR 420-90, Fire Prevention and Protection, and the DARCOM supplement to AR 420-90, Army fire department personnel and/or auxiliary firefighters will be used during periods of Army flight activities, including loading and unloading of explosives.

(i) In addition to protection provided by the host, protection will be furnished through use of portable fire extinguishers by operating agency personnel trained as auxiliary firefighters.

(j) As a minimum, four portable fire extinguishers should be available for firefighting purposes during all loading and unloading of explosives. Recommended extinguishers are: two each pressurized water type extinguishers, utilizing Aqueous Film-Forming Foam (AFFF) liquid concentrate, six percent, MIL-F-24385, and two each Potassium Bicarbonate Base Dry Chemical Extinguisher, 13.6 kilograms (30 lb) capacity.

(4) Damaged shipments. Air shipments of explosives or ammunition received at a DARCOM establishment in a damaged condition or not loaded in accordance with applicable requirements shall be reported on Discrepancy in Shipment Report (SF 361) in accordance with AR 55-38 "Reporting of Transportation Discrepancies in Shipments." If damage was due to improper preservation, packaging, or packing, SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

(5) Containers. Containers of explosives in aircraft shall not be opened or repaired.

e. *Water Transportation.*

(1) Transportation of explosives, ammunition, and other hazardous materials by water in vessels engaged in commercial service is regulated by the United States Coast Guard. Shipments overseas shall be made in accordance with the regulations of the carrier, the United States Coast Guard, or Department of the Army. (See AR 55-228, Transportation by Water of Explosives and Hazardous Cargo and TM 55-607 [Navy NAVSEA OP 3221 Rev. 1]. Loading and Stowage of Military Ammunition and Explosives Aboard Breakbulk Merchant Ships). Where route of travel requires passage under bridges, prior authorization from the responsible agency shall be obtained.

(2) Damaged shipments or shipments not stowed in accordance with pertinent regulations when received at a DARCOM establishment shall be reported on Discrepancy in Shipment Report (SF 361) in accordance with AR 55-38. If damage was due to improper preservation, packaging, or packing, SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

(3) Containers of explosives and ammunition shall not be opened or repaired onboard a vessel except as required for dumping at sea or servicing weapons.

(4) Vessels in which explosives or ammunition are received shall be inspected after unloading to see that they are clean and free from loose explosives or other flammable materials and that warning placards, etc., are removed. Explosives sweepings will be destroyed.

CHAPTER 15
DISPOSAL, DESTRUCTION, DECONTAMINATION, AND DEMILITARIZATION OF ENERGETIC MATERIALS

15-1. Introduction. Most energetic materials cannot be safely disposed of by dissolving in solution and eliminating as sewage because they are insoluble in water, are generally toxic, and are hazardous to the environment. Disposal must be by burning, detonation, or chemical decomposition. The instructions in this chapter are for destroying limited quantities of explosive, pyrotechnic, incendiary, and smoke materials normally encountered during daily operations in laboratories, manufacturing plants, and storage facilities. When larger quantities are destroyed or reclaimed, special instructions will be furnished by the US Army Armament, Munitions, and Chemical Command (AMCCOM)/US Army Materiel Development and Readiness Command (DARCOM). When destruction is authorized, the provisions of all current applicable Army directives must be observed.

15-2. Disposal. Methods for destruction are generally based on the quantity and nature of materials to be destroyed, the facilities available, and the topography of the land. Destruction of explosive materiel will be accomplished by burning or detonation. The only exception to this policy is made in the case of small quantities of explosives which can be destroyed by chemical means as specified in paragraph 15-4. Burying energetic materials in the ground or dumping in waste places, pits, wells, marshes, shallow streams, rivers, inland waterways, or deep sea is absolutely prohibited. Existing locations, if known, of buried explosives and other energetic materials shall be appropriately marked with permanent type signs and measures shall be taken to prohibit unauthorized personnel from entering the area. Existing records identifying the type and quantity of energetic materials buried shall be maintained and the burial area shall be noted on installation drawings. Explosives which are dangerously deteriorated or cannot be definitely identified shall be destroyed by an approved method. Destruction shall not be undertaken without prior approval unless the organization or installation commander decides that immediate destruction of deteriorating explosives is necessary for the protection of life and property. All deteriorated materials thus destroyed must be accounted for, since Army regulations pertaining to the disposal of excess and surplus property apply to the destruction of such unserviceable property. Prior approval for destruction of routine waste is not required. Compliance with applicable federal, state, and local environmental restrictions and permits is mandatory. Review of all SOPs for destruction of energetic materials by the Installation Environmental Coordinator is mandatory.

15-3. Destruction by Burning or Detonation.

a. *Destruction Sites.*

(1) Site selection, physical security, personnel training, emergency equipment, and procedures are governed by applicable federal, state, and local environmental regulations, particularly applicable hazardous waste regulations, and by the safety considerations which follow. Open burning and open detonation operations will be conducted in accordance with applicable air, hazardous waste, and other environmental permits. The site selected for the destruction of explosives and other energetic materials shall be located at the maximum practicable distance from all magazines, inhabited buildings, public traffic routes, and operating buildings but not less than 732 meters (2,400 feet) unless pits or similar aids are used to limit the range of fragments and debris. In all disposal and destruction activities, the quantity of explosives that may be destroyed safely at one time shall be determined carefully by starting with a limited quantity and then gradually increasing that quantity until the optimum amount consistent with safe and efficient operation is determined. When trials prove that fragments and debris are limited to lesser ranges, the appropriate inhabited building distances may be used. Sites must also be located in relation to the direction of prevailing winds so that sparks will not be blown toward explosives location. Where possible, natural barricades shall be utilized between the site and operating buildings or magazines. When destroying explosives by burning, the possibility that the mass may detonate must be recognized and appropriate protective barriers or distance separation should be used to protect personnel and property. Open air burning and detonation of explosives and pyrotechnics for demilitarization is prohibited between sunset and dawn.

(2) Dry grass, leaves, and other extraneous combustible material in amounts sufficient to spread fire shall be removed from a 200 foot radius from the point of destruction. The grounds should be of well packed earth and shall be free from large stones and deep cracks in which explosives might lodge. Explosive materials shall not be burned or detonated on concrete mats.

(3) Fire-fighting facilities shall be readily available to extinguish brush or grass fires and, if necessary, to wet down the ground between burnings and at the close of each day's operations.

(4) Ordinary combustible rubbish, explosives, and explosives contaminated material shall be destroyed at separate locations. Where limited space does not permit separate burning areas, part of the explosives destruction ground may be reserved for burning rubbish provided the two areas are not operated simultaneously, and the area where rubbish has been burned is wetted down and inspected before explosives burning is resumed. Combustible material should be burned in an incinerator complying with National Fire Protection Association Standard No. 82 or in a substantial, wire-mesh enclosure (not over three-fourths inch openings).

(5) The demolition area or burning ground shall be serviced with telephones or two-way radio communication. A change house serviced with electricity is desirable.

b. *Explosives Material Awaiting Destruction.* Explosives material awaiting destruction shall be stored at not less than intraline distance, based on the largest quantity involved, from explosives being destroyed. The material shall be protected against accidental ignition or explosion from fragments, grass fires, burning embers, or detonating impulse originating in materials being destroyed.

c. *Personnel Protection.*

(1) Operational shields with overhead and frontal protection will be provided to protect personnel. Where circumstances warrant their use, complete personnel protection shall be provided. Such structures should preferably be located at the appropriate inhabited building distance for the quantity and type of materials being detonated but in no case will this distance be less than 300 feet. Employees must use such protection when explosive materials are destroyed by detonation or when explosive materials which may detonate are being burned. When Class 1.3 material is being destroyed by burning, personnel must remain at the greatest practicable distance from the burning site but in no case shall personnel be permitted closer than the applicable public traffic route distances.

(2) During disposal and destruction operations, the number of people in the area exposed to the hazard must be kept to a minimum. Warning signs or road blocks shall be posted to restrict the area and to ensure proper segregation of activities. At least two people are needed in disposal and destruction operations and operations shall be arranged so that not all of the personnel are exposed to an incident. Personnel engaged in burning explosives should be provided with flame resistant clothing.

d. *Supervision and Training.*

(1) The disposal area and its operations shall be under the direct control of an experienced, trained supervisor responsible for all activities within the area. The supervisor shall be present during all burning and demolition ground operations. During the supervisor's absence, a competent qualified person will be in charge. The alternate shall have sole custody of all ignition devices. Prior to actual burning or detonation of explosives, all personnel including the demolition ground supervisor will be evacuated to a safe distance or protective structure affording adequate protection but consistent with the need to monitor the total operation until it is complete.

(2) Personnel employed at the destruction area shall be thoroughly trained regarding the nature of the materials handled, the hazards involved, and the precautions necessary. The danger of using unapproved, improvised methods and other deviations must be thoroughly instilled in the minds of the employees. It is essential that thorough training and vigilant supervision be provided.

(3) In the absence of specific regulations covering any phase of the destruction of explosive material, complete information will be forwarded through command channels to the Commander, DARCOM, ATTN: DRCSF, requesting instructions and guidance.

e. *Containers for Waste Explosives.* Explosives destined for the burning ground shall be in original closed packages or in containers of fire-retardant materials which will not contribute to the existing hazard by readily producing sparks when contacting rocks, steel, or other containers. Bags or containers made from easily ignited material shall not be used. Containers shall have closures that will prevent spilling or leakage of contents when handled or if overturned. Closures shall be of a type that will not pinch or rub explosives during closing and opening. The closures and surfaces of containers openings shall be thoroughly cleaned of explosive contamination to minimize the hazard during closing or opening.

f. *Servicing of Destruction Site.*

(1) Trucks transporting explosive material to burning or demolition grounds shall meet the requirements of Chapter 14. No more than two persons shall ride in the cab.

(2) Upon arriving at a burning or demolition ground, trucks may distribute explosives containers or explosives items to be destroyed at sites where destruction is to take place. As soon as all items have been removed, trucks shall be withdrawn from the burning or demolition area to a safe location until destruction is completed. Containers of explosives shall not be opened until the truck has been withdrawn

(3) Containers of energetic materials items to be destroyed at the destruction site shall be spotted and opened at least 10 feet from each other and from explosives material previously laid for destruction to prevent rapid transmission of fire in event of premature ignition.

(4) Empty containers shall be closed and moved a sufficient distance away to prevent charring or damage during burning of the explosives. Empty containers may be picked up by truck on the return trip after delivery of the next quantity to be destroyed.

(5) When materials being processed at destruction sites are to be handled by gasoline or diesel powered fork lift truck, the requirements of Chapter 12 will be observed. All such material handled will be properly packaged and must not be contaminated with explosives.

g. *General Burning Requirements.*

(1) Except in specific cases, energetic materials shall not be burned in containers.

(2) Bulk initiating explosives and others used predominantly in detonators and photoflash compositions shall be destroyed by detonation except that small quantities (not exceeding 28 grams) may be decomposed chemically.

(3) Loose explosives, other than initiating explosives, may be burned in beds not more than three inches deep. Wet explosives may require a thick bed of readily combustible material such as excelsior underneath and beyond to assure that all the explosives will be consumed once the materials are ignited. From the end of the layer of explosives the combustible material should be extended in a train to serve as the ignition point. When an ignition train of combustible material leading to the explosives is used, it must be arranged so that both it and the explosives burn in the direction from which the wind is blowing. The combustible train of the explosive, if ignited directly, must be ignited by a safety fuse of a length which will permit personnel to withdraw safely to the protective shelter, or by black powder squib initiated by an electric current controlled from a distance or structure which assures safety to personnel should the total quantity of explosives detonate. In some cases, it may be necessary to tie two or more squibs together to assure ignition of the combustible train. When a misfire occurs, personnel shall not return to the point of initiation for at least 30 minutes. Not more than two qualified persons shall be permitted to examine the misfire.

(a) Loose, dry explosives may be burned without being placed on combustible material if burning will be complete and the ground does not become unduly contaminated. The ground must be decontaminated as frequently as is necessary for the safety of personnel and operations. Qualified inspectors shall examine the sites after each burning to determine if these requirements are met. Volatile flammable liquids shall not be poured over explosives or the underlying combustible material to accelerate burning, either before or during the burning of materials.

(b) Wet explosives shall not be burned without first preparing a bed of nonexplosive combustible material upon which the explosives are placed to assure complete burning. It is usually necessary to burn RDX wet to prevent detonation.

(c) Pyrotechnic materials collected as described in paragraph 15-5h(3) may be burned, except as noted below, by emptying the containers or buckets containing the oil and pyrotechnic mixture into a shallow metal pan and igniting as described above. The opened containers may be burned with the explosives. Burning of colored smokes and WP and HC mixes requires specific authorization of the Commander, AMC, ATTN: AMCSF.

(4) Parallel beds of explosives prepared for burning shall be separated by not less than 45.7 meters (150 feet). In repeated burning operations, care must be taken to guard against material being ignited from smoldering residue or from heat retained in the ground. Burnings shall not be repeated on previously burned-over plots for 24 hours unless the burning area has been thoroughly soaked with water and an inspection of the plot by competent personnel has been made to assure the safety of personnel during a subsequent burning operation.

(5) Some types of explosives and tracer or igniter compositions give off toxic fumes when burned Proper protective respiratory equipment, such as hose masks, airline masks, and self-contained breathing apparatus shall be worn where such fumes are likely to be encountered.

h. *Materials for Detonating Explosives.*

(1) Detonation of explosives should, where practicable, be initiated by electric blasting caps using blasting machines or permanently installed electric circuits energized by storage batteries or conventional power line. Improvised methods for exploding electric blasting caps shall not be used. When items to be detonated are covered with earth, as specified in paragraph 15-3i(1), blasting caps shall not be buried beneath the ground level with the initiating charge. The initiating explosives should be primed with primacord of sufficient length to reach up through the covering to a point where the blasting cap may be connected above the ground level.

(2) Special requirements for using electric blasting caps and electric blasting circuits:

(a) Electric blasting caps, other electric initiators, electric blasting circuits and the like may be energized to dangerous levels by extraneous electricity such as: static electricity, galvanic action, induced electric currents, high tension wires, and radio frequency energy from radio, radar, and television transmitters. Safety precautions shall be taken to reduce the probability of a premature initiation of electric blasting caps and explosives charges.

(b) The shunt shall not be removed from the lead wires of the blasting cap until the moment of connecting them to the blasting circuit, except during electrical continuity testing of the blasting cap and lead wires. The individual who removed the shunt should ground himself or herself by grasping the firing wire prior to performing the operation in order to prevent accumulated static electricity from firing the blasting cap.

NOTE

After electrical continuity testing of the blasting cap, the lead wires must be short-circuited by twisting the bare ends of the wires together immediately after testing. The wires shall remain short circuited until time to connect them to the blasting circuit.

(c) When uncoiling the lead wires of blasting caps, the explosives end of the cap should not be held directly in the hand. The lead wires should be straightened out as far as necessary by hand and shall not be thrown, waved through the air, or snapped as a whip to unloosen the wire coils. Avoid loops by running lead wires parallel to each other and close together. If loops are unavoidable, keep them small. Keep wires on the ground in blasting layouts.

(d) Firing wires shall be twisted pairs. Blasting circuit firing wires shall at all times be twisted together and connected to ground at the power source and the ends of the circuit wires where blasting cap wires are connected except when actually firing the charge or testing circuit continuity. The connection between blasting caps and circuit firing wires must not be made unless the power end of the circuit lead (firing wires) are shorted and grounded. The following methods should be followed when connecting electric type blasting cap lead wires to the firing circuit wires:

1 Check wires leading to the blasting machine for continuity and stray currents.

2 Test electric blasting cap wires for electrical continuity, and after the test, connect to wires leading to the blasting machines.

3 Evacuate all but two persons from the area. Place cap into charge to be detonated.

4 Unshort firing lead wire circuit and check for continuity.

5 Connect firing lead wire to blasting machine and fire charges.

6 After firing, remove lead wires from blasting machine and twist the end to short them.

(e) Electric blasting or demolition operations and unshielded electric blasting caps should be separated from radio frequency energy transmitters by the minimum distances specified in tables 15-1, 2, and 3. These distances apply to all parts of the operation, including the lead wires of the cap and the firing wires circuit. Before connecting electric blasting caps to the firing wires, the blasting circuit must be tested for the presence of extraneous electricity by the following test:

1 Arrange a dummy test circuit, essentially the same as the actual blasting circuit except that a No. 47 radio pilot lamp of known good quality inserted in place of the blasting cap shall be used without applying electric current to the circuit. Any glow is evidence of the presence of possible dangerous amounts of RF energy and blasting operations in such areas must be performed with non-electric blasting caps and safety fuse.

2 The Dupont Blaster's Multimeter, Model 101, may be substituted for the No. 47 radio pilot lamp. If the exposure is to radar, television, or other microwave transmitters, the actual blasting circuit, with blasting cap included, but without other explosives shall be used to test for extraneous electricity. Personnel performing such tests must be provided protection from the effects of an exploding blasting cap. Distances prescribed in tables 15-1, 2, and 3 should be used as a guide in the selection of sites for electric blasting operations in the vicinity of radar and other microwave transmitters.

Table 15-1. Minimum Safe Distances Between RF Transmitters and Electric Blasting Operations

Transmitter power (watts)	Minimum safe distance meters (feet)			
	Commercial AM broadcast transmitters		HF transmitters other than AM broadcast	
100	228.6	(750)	228.6	(750)
500	228.6	(750)	518.2	(1,700)
1,000	228.6	(750)	731.5	(2,400)
4,000	228.6	(750)	1,463.0	(4,800)
5,000	259.1	(850)	1,676.4	(5,500)
10,000	396.2	(1,300)	2,316.5	(7,600)
25,000	609.6	(2,000)	3,657.6	(12,000)
50,000[1]	853.4	(2,800)	5,181.6	(17,000)
100,000	1,188.7	(3,900)	7,315.2	(24,000)
500,000[2]	2,682.2	(8,800)	16,764.0	(55,000)

[1]Present maximum power of US broadcast transmitters in Commercial AM Broadcast Frequency Range (0.535 to 1.605 MHz).

[2]Present maximum for international broadcast.

Table 15-2. Minimum Safe Distances Between Mobile RF Transmitters and Electric Blasting Operations

Transmitter Power Watts	Minimum Safe Distances Meters (Feet)									
	MF 1.6 to 3.4 MHz Industrial		HF 28 to 29.7 MHz Amateur		VHF 35 to 36 MHz Pub. Use 42 to 44 MHz Pub. Use 50 to 54 MHz Amateur		VHF 144 to 148 MHz Amateur 150.8 to 161.6 MHz Public Use		UHF 450 to 460 MHz Public Use	
5[1]										
10	12.2	(40)	30.5	(100)	12.2	(40)	4.6	(15)	3	(10)
50	27.4	(90)	67	(220)	27.4	(90)	10.7	(35)	6.1	(20)
100	38.1	(125)	94.5	(310)	39.6	(130)	15.2	(50)	9.1	(30)
180[2]							19.8	(65)	12.2	(40)
250	61	(200)	149.4	(490)	62.5	(205)	22.9	(75)	13.7	(45)
500[3]					88.4	(290)				
600[4]	91.4	(300)	231.6	(760)	96	(315)	35	(115)	21.3	(70)
1,000[5]	122	(400)	298.7	(980)	125	(410)	45.7	(150)	27.4	(90)
10,000[6]	381	(1,250)			396.2	(1,300)				

[1]Citizens band radio (walkie-talkie) (26.96 to 27.23 MHz) - Minimum safe distance - five feet.

[2]Maximum power for 2-way mobile units in VHF (150.8 to 161.6 MHz range) and for 2-way mobile and fixed station units in UHF (450 to 460 MHz range).

[3]Maximum power for major VHF 2-way mobile and fixed station units in 35 to 44 MHz range.

[4]Maximum power for 2-way fixed station units in VHF (150.8 to 161.6 MHz range).

[5]Maximum power for amateur radio mobile units.

[6]Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

Table 15-3. Minimum Safe Distances Between TV and FM Broadcasting Transmitters and Electric Blasting Operations

Effective radiative power (watts)	Minimum safe distances meters (feet)					
	Channels 2 to 6 and FM		Channels 7 to 13		UHF	
up to 1,000	304.8	(1,000)	228.6	(750)	182.9	(600)
10,000	548.6	(1,800)	396.2	(1,300)	182.9	(600)
100,000[1]	975.4	(3,200)	701	(2,300)	335.3	(1,100)
316,000[2]	1,310.6	(4,300)	914.4	(3,000)	442	(1,450)
1,000,000	1,767.8	(5,800)	1,219.2	(4,000)	610	(2,000)
5,000,000[2]	2,743.2	(9,000)	1,889.8	(6,200)	914.4	(3,000)
10,000,000	3,109	(10,200)	2,255.5	(7,400)	1,066.8	(3,500)
100,000,000					1,828.8	(6,000)

[1]Present maximum power, channels 2 to 6 and FM.

[2]Present maximum power, channels 7 to 13.

[3]Present maximum power, channels 14 to 83.

(f) Blasting or demolition operations shall not be conducted during an electrical storm or when a storm is approaching. All operations shall be suspended, cap wires and lead wires shall be short-circuited, and all personnel must be removed from the demolition area to a safe location when an electrical storm approaches.

(g) Prior to making connections to the blasting machine, the firing circuit shall be tested with a galvanometer for electrical continuity. The individual assigned to make the connections shall not complete the circuit at the blasting machine or at the panel, nor shall he/she give the signal for detonation until he/she is satisfied that all persons in the vicinity are in a safe place. When used, the blasting machine or its actuating device shall be in this individual's possession at all times. When the individual uses a panel, the switch must be locked in the open position until ready to fire and the single key or plug must be in his/her possession.

(h) Electric blasting caps must be in closed metal boxes when being transported by vehicles equipped with two-way radios and also when in areas where extraneous electricity is known to be present or is suspected of being present.

(3) Safety fuses may be used in the detonation of explosives where methods described in 15-3h(1) above cannot be accomplished. Safety fuse, when used, must be tested for burning rate at the beginning of each day's operation and whenever a new coil is used. Sufficient length of fuse shall be used to allow personnel to retire to a safe distance, but under no circumstances should a length be less than three feet or have less than 120 second burning time. Crimping of fuse to detonators must be accomplished with approved crimpers. Safety fuse which is too large in diameter to enter the blasting cap without forcing shall not be used. Before igniting the safety fuse, all personnel except the supervisor and not more than one assistant shall retire to the personnel shelter or be evacuated from the demolition area.

(4) When using blasting caps involving the electric or non-electric system of destruction, the explosives end of the blasting cap shall always be pointed away from the body.

i. *Detonation of Explosives.*

(1) Explosives to be destroyed by detonation should be detonated in a pit not less than four feet deep and covered with not less than two feet of earth. The components should be placed on their sides or in position to expose the largest area to the influence of the initiating explosives with an adequate number of demolition blocks placed in intimate contact on top of the item to be detonated and held in place by earth packed over the demolition blocks. Bulk explosives can be used as a substitute for demolition blocks. Where space permits and the demolition area is remotely located from inhabited buildings, boundaries, work areas, and storage areas, detonation of shells and explosives may be accomplished without the aid of a pit. In either event, however, the total quantity to be destroyed at one time, dependent on local conditions, should be established by trial methods to assure that adjacent and nearby structures and personnel are safe from the blast effect or missiles resulting from the explosion Rocket solid propellants should not be destroyed by detonation (paragraph 15-3p).

(2) After each detonation, a search shall be made of the surrounding area for unexploded materials. Lumps of explosives may be picked up and prepared for the next detonation.

(3) In case of misfires, personnel shall not return to the point of detonation for at least 30 minutes after which not more than two qualified persons shall be permitted to examine misfire.

(4) AR 95-50 outlines the organization and functions of Regional Airspace Subcommittees and establishes uniform procedures for the handling of airspace problems. DARCOM installations will request, through channels, airspace clearance for demolition ground activities in accordance with these regulations.

j. *Dynamite*. Unopened boxes of exuding dynamite to be destroyed should be burned on a bed of combustible material without being opened. Precautions must be taken to protect personnel and property from possible detonation. Individual cartridges may be burned in a single layer not greater in width than the length of one cartridge, on a bed of combustible material. Dynamite awaiting destruction shall be shielded from the sun. Frozen dynamite is more likely to detonate during burning than normal cartridges. Destruction of dynamite by detonation may be accomplished where the location will permit this method of destruction. Care in priming to assure complete detonation of the quantity must be taken.

k. *Initiating Explosives*. When relatively large quantities of initiating explosives such as lead azide or mercury fulminate are to be destroyed, detonation is the best method. The bags containing the explosives should be kept wet while being transported to the demolition area. A predetermined number of bags should be removed from the containers, carried to the destruction pit, placed in intimate contact with each other and blasting caps used to initiate the explosives. The remaining explosives shall be kept behind a barricade with overhead protection during the destruction operations and located at a distance that will assure safety.

l. *RDX and PETN*. RDX and PETN may be burned as described in paragraph 15-3g. Since RDX and PETN are usually collected wet, they should be spread out and partially dried prior to burning. If the wet material will burn incompletely and with difficulty on the combustible bed, before any preparation for initiation is attempted fuel oil may be sprinkled over the bed of combustible material upon which the explosive is placed.

m. *Propelling Charges*. Propelling charges with igniters may be burned without slitting but in all cases igniter protector caps shall be removed from the charges to be burned. Protection must also be provided against possible projection of the charges and explosion. Propelling charges must not be piled one on the other but shall be burned in single layer of charges laid side by side. Core igniter type charges in the single layer should be separated by a distance equal to one caliber.

n. *Black Powder.*

(1) Black powder is best disposed of by dissolving out the potassium nitrate in a closed system and disposing of the solid wastes separately. It may also be burned as described below. Upon drying, wet black powder may retain some of its explosive properties since the nitrate may not have been removed completely.

(2) Only tools of wood or spark-resistant metal will be used in opening the containers. The contents of only one container will be burned at one time; no quantity should exceed 50 pounds. The powder must be removed from the container and spread on the ground in a train approximately two inches wide, so that no part of the train comes closer than 10 feet to another part. To ignite the powder bed, use a train of flammable material approximately 25 feet in length placed so that the train and the bed of powder burn into the direction from which the wind is blowing. Emptied black powder containers will be thoroughly washed with water. Serious explosions have occurred during handling of supposedly empty black powder cans. Safety precautions shall be observed.

o. *Pyrotechnic Materials*. Loose pyrotechnic materials should be burned under the same conditions as black powder. Water-wet pyrotechnic materials may be burned in small quantities in furnaces designed and approved for that purpose.

p. *Rocket Solid Propellants.*

(1) Wherever practicable, propellant must be removed from rocket motors and destroyed by burning. In the event removal of the propellant is not practicable, the rocket motor should be positioned or restricted to prevent movement and propellant in the units shall be destroyed by static firing. When units are to be destroyed by static firing, complete details of the procedures must be submitted to the Commander, DARCOM, ATTN: DRCSF for approval.

(2) Rocket or missile propellants (solid) may weigh as much as several thousand pounds per grain and the polymer-oxidizer type may be extremely difficult to ignite at atmospheric pressures. Large size rocket motors for specific systems may be destroyed in accordance with instructions contained in technical manuals or technical bulletins applicable to such systems.

15-4. Destruction by Chemical Means. The chemical destruction of loose explosives, except as provided below, shall not be permitted unless approval is given by the Commander, DARCOM. Chemical methods must be supervised by qualified personnel having knowledge of chemistry. Chemical methods shall not be used in an attempt to destroy explosives which are enclosed or pressed into components such as detonators. The following procedures may be used under adequate supervision for 28 grams or less of the explosives named.

a. *Mercury Fulminate.* Place a quantity of aqueous sodium thiosulfate (hypo) solution (20 percent by weight of sodium thiosulfate) equal to 10 times the weight of mercury fulminate to be destroyed in a wood or earthenware container. While agitating the hypo solution, add water-wet mercury fulminate. The mixture shall be agitated by air or mechanical means but not by hand. Agitation must be continued until all fulminate has been dissolved, usually within two hours. Operators shall keep to the windward of the container or wear gas masks to avoid inhaling any cynogen gas evolved.

b. *Nitroglycerin.* Small quantities of nitroglycerin may be neutralized or destroyed with a mixture of the following solutions:

Solution A. Sodium sulfide (pulverized) (nine parts by weight) and water (30 parts by weight).

Solution B. Denatured ethyl alcohol (70 parts by weight) and acetone (20 parts by weight).

Do not combine the two solutions until immediately before use since potency of the mixed solutions diminishes on storage. This mixture should be used only for very small quantities of nitroglycerin (e.g., the oily film that adheres to surfaces after the nitroglycerin has been removed with sponges or absorbed in wood pulp or sawdust). Operators using this solution should wear rubber gloves.

c. *Black Powder.* Black powder may be completely destroyed by leaching or washing with large quantities of water and disposing of the washings separately from the residue.

d. *Lead Azide.*

(1) Lead azide accumulated on surfaces should be taken up with water wet cloths. The cloths should then be washed out in one of the solutions named below after which the complete desensitizing treatment is carried out in the solution. The cloths should be thoroughly washed with water before reuse. Empty shipping bags should be turned inside out and treated while still water-wet.

(2) The preferred chemical method for destroying lead azide is to use a 20 to 25 percent aqueous solution of ceric ammonium nitrate. When small quantities of lead azide are destroyed in this manner the reaction is not violent. Since one of the products of the reaction is a gas, the ending of the gas evolution indicates completion of destruction.

15-5. Decontamination.

a. *Decontamination Requirements.*

(1) The cleansing of equipment, buildings, and grounds of explosive materials is a difficult, tedious, and sometimes hazardous operation. Because of the wide variety of materials, the existence of cracks, crevices, and cavities, and the possibility of explosions and the evolution of toxic or explosive gases, the operations and techniques must be made as simple as possible and various precautions taken to ensure safety of personnel and completeness of decontamination. Serious accidents have occurred through the subsequent handling or heating of incompletely decontaminated equipment. DARCOM Safety Manual and DARCOM Regulations 385-series provide detailed safety measures.

(2) Loading plants, because of the use of a number of explosive materials, present particularly difficult problems of decontamination. The procedures appropriate to several different explosives manufacturing plants may be required for the decontamination of different parts of an individual loading plant.

(3) With the growing complexity of modern military explosives and propellants because of the introduction of new nonexplosive ingredients as well as mixtures of explosives, the problem of decontamination is increased correspondingly. New and special compositions, therefore, should be given careful technical consideration before decontamination operations are undertaken.

(4) A necessary function of decontamination is the collection of industrial wastes for destruction or reclamation. Elaborate controls are required to assure that these collection efforts are performed safely and economically without causing down-time in essential operations.

b. *Decontamination and Dismantling Explosives Establishments.* The decontamination and dismantling procedures to be followed for explosives establishments upon cessation of activity or upon conversion to other uses shall be outlined in detail as prescribed in TB 700-4. Requirements shall be developed for cleaning and dismantling equipment preparatory to repair or maintenance. Any equipment used in an explosive operation which may subsequently be used in operations with non-explosive material or explosives other than that for which the equipment was used originally shall first be given whatever treatment is necessary to insure that no explosive material remains. Decontamination markings and the use of DA Form 3803, Materiel Inspection Tag, should be included as a part of these requirements.

c. *Decontamination Operations.*

(1) Wherever practicable, decontamination is affected by the physical operations of washing, steaming, and vacuuming. While washing operations suffice for most pyrotechnic materials, some smoke and incendiary compositions present explosion hazards when wet with water. A small amount of water contacting hexachloroethane (HC) smoke mixture may cause an explosion and release of toxic fumes. Metal objects such as nitrators, centrifuges, tanks, piping, etc. are washed with water and steamed. Wooden objects such as railings, paddles, etc. and buildings such as dry-houses, and packing materials, gaskets, etc., are destroyed by removing and burning after preliminary cleaning. Earth that is so contaminated as to offer a fire or explosion hazard is wetted, scraped up, and burned at a burning ground.

(2) Free acid present in equipment requires neutralization as well as washing and a five percent solution of sodium carbonate (soda ash) is used for this purpose. Because of the uncertainty of complete removal of explosives in all cases by the physical methods described, chemical methods are used also to supplement these. Standard decontamination procedures include the decontaminating chemical shown by table 15-4.

d. *Collection of Contaminated Industrial Wastes.* Industrial wastes which may contain explosive materials and chemical agents shall be collected only in holding, storage, or disposal facilities specifically designed and permitted (i.e., having environmental operating permits) for that purpose. Disposal into sanitary sewers, septic tanks, sanitary filter tanks, and unlined sumps, settling basins, or leaching pits is prohibited except as specifically authorized by permit. Sumps should be desensitized and cleaned at regular intervals. Cracks and crevices may contain explosives residue. Such residue must not be subjected to impact or friction from such sources as high pressure water streams, scraping tools or devices, etc., which may initiate the sensitive explosives. Quantities of initiating explosives in excess of 28 grams shall be destroyed by burning or detonation (see paragraph 15-3). Explosive materials to be removed from a settling basin should be maintained wet until removed. The more sensitive explosives should be maintained wet until destroyed. Materials containing powdered metals should be kept under water to prevent any dangerous rise in temperature which might otherwise be developed in the reaction between the metals and a small quantity of water.

Table 15-4. Decontaminating Chemicals

Contaminant	Decontaminating chemical
Lead azide	Ceric ammonium nitrate
Mercury fulminate	Sodium thiosulfate
Nitroglycerin	Methanolic sodium sulfite
Nitrocellulose	Sodium hydroxide
Smokeless powder	Sodium hydroxide and acetone
TNT	Sodium carbonate and sellite
Tetryl	Sodium carbonate and sellite or acetone
Pentolite	Acetone
White phosphorus	Copper sulphate solution

e. *Deposition from Waste Liquids.* When sumps or basins are properly designed, the wash water which passes beyond filters and basins should be free from significant amounts of explosive materials. If the effluent is discharged into a public stream, river, etc, it must not contain more explosives than permitted by local and state regulation. Consideration should be given to the possibility of deposition of explosive materials on the banks of streams or marshes during periods of drought, as well as to any possible subsequent precipitation of explosives with change of temperature, acidity, or concentration of the waste water. Where uncertainty exists regarding the composition of waste waters, competent technical advice and assistance should be obtained.

f. *Handling Water-Soluble Materials.* Where ammonium picrate, black powder, or other materials which are appreciably soluble in water are handled, the amount of dissolved material should be kept as low as practicable. Floors should be swept before washing down to reduce the quantity of dissolved material in the wash water.

g. *Destruction of Collected Solid Wastes.* Contaminated solid waste material should be taken in closed containers, as soon as practicable, to buildings set apart for its treatment or to the burning ground to be destroyed in an appropriate manner. Collected explosive and chemical wastes must not be disposed of by being buried or thrown in any streams or tidewater unless they are decomposed by water. Disposal of decomposed wastes in streams or tidewater will be allowed only if permitted by federal, state, and local laws and regulations.

h. *Collection of Explosives Dusts.*

(1) Dust collecting systems may be used to aid cleaning, to lessen explosion hazards, and to minimize industrial job-incurred poisoning and dermatitis.

(2) Examples of high explosives dusts which may be removed by a vacuum system are TNT, tetryl, ammonium picrate, composition B, and pentolite. A wet collector, which moistens the dust close to the point of origin and keeps it wet until the dust is removed for disposal, is preferred except for ammonium picrate which should be collected in a dry system.

(3) More sensitive explosives such as black powder, lead azide, mercury fulminate, tracer, igniter, incendiary compositions, and pyrotechnic materials may be collected by vacuum in this manner, provided they are kept wet with the wetting agent, close to the point of intake. The vacuum (aspirator) systems must be so arranged that the various types of explosives are collected separately or in a manner to avoid mixture of dissimilar hazards; i.e., black powder with lead azide. Provision should be made for the proper liberation of gases that may be formed. The use of vacuum systems for collecting these more sensitive materials should be confined to operations involving small quantities of explosives; for example, in operations involving fuzes, detonators, small arms ammunition, and black powder igniters. Potential fire and explosion hazards can be minimized by collecting scrap pyrotechnic, tracer, flare, and similar mixtures in No. 10 mineral oil. Satisfactory techniques include placing the oil in catch pans and scrap transporting containers at the various operations throughout the plant, and by having individual oil containers serve as collection points for multiple operations. In the latter case, nominal quantities of dry scrap may accumulate at operating locations before they are delivered to collection points and placed in containers of oil. The level of oil should be kept at least 2.54 centimeters (one inch) above the level of any pyrotechnic mixture in the containers. Containers in which scrap explosives and pyrotechnic materials have been collected should be removed from the operating buildings for burning at least once per shift. Where oil is used, fire-fighting equipment satisfactory for Class B fires should be available. Carbon dioxide or foam extinguishers are recommended.

i. *Location of Collection Chambers.*

(1) Wherever practicable, dry type explosives dust collection chambers, except portable units as specifically provided for in paragraph 15-5j(3), should be located outside operating buildings in the open or in buildings exclusively set aside for the purpose. In order to protect operating personnel from an incident involving the collection chamber, a protective barrier must be provided between the operating building and the outside location or separate building where the collection chamber is placed. If the collection chamber contains 11.35 kilograms (25 pounds) of explosives or less, the protective barrier may be a 30.5 centimeters (12 inch) reinforced concrete wall located at least 2.44 meters (eight feet) away from the operating building. The collection chamber must be separated from cubicle walls by at least three feet. If the collection chamber contains more than 11.35 kilograms (25 pounds) of explosives and is separated from the operating building by a 30.5 centimeters (12 inch) reinforced concrete wall, the wall must be separated from the operating building by a minimum of unbarricaded intraline distance. The cubicle may be placed at a minimum of barricaded intraline distance from the operating building if the protective barrier meets the requirements of DARCOM safety regulations for operational shields (including the required three foot distance between the barrier and the explosives) and for the quantity of explosive in the collection chamber, or if the barrier complies with the requirements of paragraph 12-11v for barricades. Barricaded and unbarricaded intraline distances will be based on the quantity of explosives in the collection chamber.

(2) When it is not practicable to locate dry type collection chambers outside the operating building, a separate room within the building may be set aside for the purpose. This room shall not contain other operations nor shall it be used as a communicating corridor or passageway between other operating locations within the building when explosives are being collected. Walls separating the room from other portions of the operating buildings must meet the requirements specified in DARCOM safety regulations for the quantity of explosives in the collecting chamber. If more than one collection chamber is to be located in the room, the room must be subdivided into cubicles by walls meeting the requirements of DARCOM safety regulations and not more than one collection chamber shall be in a single cubicle.

(3) Stationary and portable wet type collectors may be placed in the explosives operating bays or cubicles provided the quantity of explosives in the collectors does not exceed five pounds. If placed in separate cubicles, the explosives limits for the collectors may be increased to the amount reflecting the capabilities of the cubicle walls as operational shields. For greater quantities, the location requirements set forth above are applicable.

j. *Design and Operation of Collection Systems.*

(1) Collection systems and chambers shall be designed to prevent pinching explosives (especially dust or thin layers) between metal parts. Pipes or tubes through which dusts are conveyed should have flanged, welded, or rubber connections. Threaded connections are prohibited. The system shall be designed to minimize accumulation of explosives dusts in parts other than the collection chamber. Accordingly, pipes or ducts through which high explosives are conveyed shall have long radius bends with a centerline radius at least four times the diameter of ducts or pipes. Short radius bends may be used in systems for propellant powder provided they are stainless steel with polished interiors. The number of points of application of vacuum should be kept to a minimum. So far as practicable, each room requiring vacuum collection chambers, but not more than two bays, shall be serviced by a common header to the primary collection chamber. Wet primary collectors are preferred. Not more than two primary collectors (wet or dry type) should be connected to a single secondary collector. If an operation does not create a dust concentration which may produce a severe health hazard, manual operation of the suction hose to remove explosives dusts is preferred to a permanent attachment to the explosive dust producing machine. A permanent attachment increases the likelihood of propagation through a collection system of a detonation occurring at the machine. Interconnection of manually operated hose connections to explosives dust-producing machines should be avoided.

(2) Two collection chambers should be installed in series ahead of the pump or exhauster to prevent explosives dust from entering the vacuum producer in dry vacuum collection systems.

(3) Dry type portable vacuum collectors shall not be located in a bay or cubicle where explosives are present or in inclosed ramps but may be positioned outside the building or in a separate cubicle having substantial dividing walls for quantities of explosives not exceeding five pounds. Wet type portable vacuum collectors may be placed in explosives operating bays or cubicles provided the quantity of explosives in the collector is limited in accordance with the requirements of paragraph 15-5i. For dry collection of quantities in excess of 2.3 kilograms (five pounds) or wet collection of quantities in excess of 6.8 kilograms (15 pounds), the further provisions of paragraph 15-5i shall apply.

(4) The design of wet collectors shall provide for proper immersion of explosives, breaking up air bubbles to release airborne particles, and removal of moisture from the air before it leaves the collector to prevent moistened particles of explosives from entering the small piping between the collector and the exhauster or pump.

(5) At least once every shift, explosives dust shall be removed from the collector chamber to eliminate unnecessary and hazardous concentrations of explosives. The entire system should be cleaned weekly, dismantling the parts if necessary.

(6) The entire explosives dust collecting system shall be electrically bonded and grounded. The grounds must be tested frequently.

(7) Slide valves for vacuum collection systems are permitted. There shall be no metal-to-metal contacts with the metal slide. An aluminum slide operating between two ebonite spacer bars will not constitute a hazard.

15-6. Demilitarization.

a. *Pollution Abatement and Waste Recycling Requirements.* The problem of what to do with outdated ammunition to prevent both pollution and hazardous situations from occurring is an enormous one which dates back more than a century. At first glance, two answers become apparent, i.e., complete disposal or partial disposal with some recycling. The various chemical constituents of the warhead, propellant, or pyrotechnic are not only explosively hazardous but are frequently of a toxic character. Disposal by dumping into the world's oceans, incineration, or detonation have been shown to be not only dangerous but an addition to world pollution and as such, a persistant universal health hazard. Further, the problem of pollution from all sources (military and non military) became so acute in the United States in the early 1970's that both Presidential Executive Orders and Congressional legislation required that federal and private facilities be set up or converted to handle both pollution abatement and waste recycling. To this end, all US Military services (plus the AEC, now NRC) launched or vigorously continued their efforts to develop safe, efficient, and non-polluting methods of disposal or recycling of outdated ammunition, in particular, their energetic material content.

b. *Recovery and Reclamation of Energetic Materials.* Certain energetic materials such as relatively stable high explosives and pyrotechnics can be easily reclaimed and reloaded, but solid propellants which may have a limited storage life, require significant degrees of processing before they can be recycled or converted to other products. In many instances energetic material component recovery was not economically feasible. Energy conservation requirements strongly favor the recycling of energetic materials over pollution-free disposal (or the wasting) of these materials.

c. *Redesign of Ammunition for Use of Recycled Energetic Materials.* To have a safe, effective, and efficient program of ammunition recycling, ammunition that can be readily recycled must be available. To this end a new concept in ammunition design has been evolved. Ammunition items (inclusive of explosives, propellants, and/or pyrotechnics) will be designed and fabricated in such a manner as to be easily and safely recycled.

d. *Explosives Reclamation.* Preliminary removal of the high explosive charge from a mine, projectile, or shell usually involves the use of hot water or steam to liquefy the explosive which is then separated from the water by gravity, or contour drilling followed by high pressure water erosion to remove the high explosive residue. The new concept of ammunition which can be readily recycled by design, however has resulted in the prepackaging or encapsulation of the entire high explosive charge for easy and safe removal. After separation of the casing from the charge, table 15-5 summarizes the various procedures which have been developed to recover the individual constituents of the charge.

Table 15-5. High Explosive Reclamation

Constituent-composition	Explosive recovery technique
HBX from H-6 composition	A hot water erosion process removes the HBX from the warhead. Then the water explosive mixture flows into a vacuum kettle where the water is removed. The dried explosive is then dispensed through a multiported dispenser to an endless steel belt where it solidifies and is broken into flakes as it flows off the belt. Remelting and composition adjustment to form new HBX types or H-6 is then easily performed.
HMX from PBX 9404 composition	Preferential extraction of the binder is performed with concentrated (70 percent) technical grade nitric acid by adding the acid to the PBX component and heating the mixture to between 70°C and 95°C for several minutes. After cooling to room temperature, the excess acid is withdrawn. The extraction procedure is repeated until the HMX is free of the binder. The acid is then diluted with water and the HMX collected by vacuum filtration. Yield is 82.0 to 86.6 percent.

Table 15-5. High Explosive Reclamation (Cont)

Constituent-composition	Explosive recovery technique
HMX from PBX compositions developed after 1974	The binders which are incorporated in these post-1974 compositions are selected for their heat sensitivity. For example, polypropylene-glycol-urethane can be degraded when heated to 160°C for 10 hours. The HMX can then be extracted with methylene chloride.
RDX from RDX composition A and RDX and TNT RDX composition B	Selective batch extraction of the wax in composition A using benzene in a soxhlet apparatus leaves the RDX. The TNT in composition B is extracted either batchwise or continuously in from soxhlet apparatus with benzene subsequent to extraction of the wax with heptane. This procedure leaves the RDX intact.
RDX plus 0.03 percent desensitizer from composition A-3	The wax is removed (leaving the RDX) by selective solution using a batch process in which a benzene-water azeotrope is continuously circulated through an agitated composition A-3/benzene slurry.
RDX from composition B	Selective solution of TNT and desensitizer with benzene in a closed system.
RDX from composition C-3	Selective solution of all but the RDX content of the composition is accomplished by agitation of a slurry of composition C-3 and methanol (or acetone) in a kettle.
Tetryl from tetryl-metal stearate mixture	Tetryl is selectively dissolved by continuous acetone extraction followed by water precipitation to recover the tetryl.
Tetryl from tetryl-stearic acid mixture	Separation is accomplished by reaction of the mixture with a dilute solution of the sodium bicarbonate or carbonate at 90°C, cooling to room temperature, and then washing the tetryl with cold water. The tetryl is then recrystallized from acetone-water. Large pellets of the tetryl-stearic acid mixture require pre-treatment with an acetone soak.
TNT from amatol	The TNT is extracted with boiling water through a stainless steel mesh thus removing dirt and metal impurities. After the molten TNT settles, it is drawn off and rewashed with boiling water under agitation four times in a similar fashion. The TNT is then precipitated in cold water or run directly into graining kettles for immediate reuse.
TNT from 10/90 and 50/50 pentolite	TNT is selectively dissolved with benzene at 70°C followed by cooling, filtering, and evaporation of the benzene to obtain the TNT.
TNT and tetryl from tetrytol 75/25	TNT is selectively dissolved using a xylene-heptane (50/50) mixture. This procedure recovers 90 percent of the tetryl.
TNT from warheads	TNT is selectively dissolved using xylene.

e. *Propellants Reclamation.* Solid ammunition propellants are difficult to recycle because the smokeless base(s) (nitrocellulose and/or nitroguanidine) used in the ammunition will deteriorate with age. Solid rocket propellants in many instances can be recovered as shown in table 15-6. However, the polymeric binder used in solid rocket propellants is a cross-linked material which is insoluble in solvents making it impossible to remove the binder simply by solvent extraction. Furthermore, the finely divided metal and oxidizer particles are intimately coated with the binder which is also impervious to water making it impossible to remove a water-soluble oxidizer from the metal and binder. This impediment in recycling calls for chemical cleavage of the binder linkage or the use of binder molecular structures which can be thermally degraded. Liquid propellants, on the other hand, do not present much of a recycling problem. They usually consist of a fuel and an oxidizer which are both usually basic industrial chemicals that can be stored separately for an indefinite period of time. Hence, liquid propellants are always essentially recovered before actual use.

Table 15-6. Propellant Reclamation

Constituent-ammunition item or composition	Propellant constituent recovery technique
Ammonium perchlorate (or other oxidizer) and fuel from binder	The oxidizer is usually water-soluble. The oxidizer extraction process is efficiently performed with the cooling water used to cool the propellant grains during the shredding process. The oxidizer is then recrystallized and reused. The inert binder and metal fuel are further separated for the purpose of recovering the metal either before or after incineration.
Contaminants from .50 cal ammunition	The removal of contaminating igniter and tracer compositions from .50 cal propellant is performed by selective solution using a water spray from a fish-tail type of sprayer which emits the water at a 90 degree angle to the surface of the propellant powder as it is vibrated on a Day Roball Gyrator screen.
Nitrocellulose from deteriorated propellants	Recovery of nitrocellulose is performed by solution or dispersion under water, then careful molding to give a colloidal composition of nitrocellulose.
Nitrocellulose from single-base cannon powder containing DNT and dibutylphthalate (DBP)	Preferential solution of the DNT and DBP uses an extraction process with a mixture of benzene water.
Nitroglycerin propellants	A process of selective adsorption is used; i.e., a benzene solution of the various constituents of the composition are selectively adsorbed on materials such as Fullers earth, silicic acid, activated carbon, activated silicates, etc., followed by a desorption process.
Reclamation of cured polysulfide-perchlorate propellants	The waste cured propellant is reduced to a small particle size by passing it through a laboratory mill. It is then added to the extent of 20 percent of the total mixture to a normal mixture of propellant. The waste propellant re-liquefies to its precured state in the mixer by means of a molecular weight redistribution between the low molecular weight liquid polymer and the high molecular weight solid polymer. The reaction is complete in about 10 minutes.

f. *Pyrotechnics Reclamation.* As can be seen from the data in table 15-7, little work has been done on recycling the majority of pyrotechnic basic materials with the exception of the magnesium and sodium nitrate in illuminating flares and dyes in smoke components. Current investigations consist of attempts to recover the pyrotechnic materials from signal flares. However, the work to date can be considered as a pilot activity which can be further developed and applied to other pyrotechnic items and components.

Table 15-7. Pyrotechnic Reclamation

Constituent-composition	Pyrotechnic constituent recovery technique
Dyes from smoke compositions	Preferential solution with water leaves the dye plus other water insolubles for storage and later reuse in new units. The dyes can be further separated by extraction with a dilute aqueous mineral acid such as hydrochloric acid. If water is present in the dye, it can be extracted with alkaline solutions.
Magnesium from flare compositions	Water is used to selectively dissolve sodium nitrate and most of the binder material. The residual magnesium is then dried and sieved. In some instances the binder requires acetone or similar solvents.

APPENDIX A
CHARACTERISTICS AND DATA

Table A-1. Sensitivity Test Values of Explosives

Material	Impact test with 2 kilogram weight		Pendulum friction test, percent explosions	Rifle bullet test, percent explosions	Explosion temperature test, °C	Minimum detonating charge, gram of-		Electrostatic sensitivity, joules
	PA APP (% TNT)	BM APP (% TNT)				lead azide	mercury fulminate	
Primary explosives								
Lead azide (pure)	29		100	-	-	-	-	0.01
DLA	29 to 43	13 to 28	-	-	340	-	-	-
SLA	14	30	-	-	350	-	-	-
CLA	14 to 21	-	-	-	-	-	-	-
PVA-LA	29 to 35	13 to 16	-	-	344	-	-	-
RD-1333	36	15	-	-	340	-	-	-
DCLA	21 to 42	-	-	-	345	-	-	-
Mercury fulminate	14	5	100	-	210	-	-	0.025
Diazodinitrophenol	14	5	100	-	195	-	-	0.25
Lead styphnate (normal)	21	8	-	-	282	-	-	0.0009
Tetracene	14	7		-	160	-	-	0.01
Aliphatic nitrate esters								
BTN	7	16	-	-	230	-	-	-
DEGN	-	-	-	-	237	-	-	-
Nitrocellulose								
Pyrocellulose (12.75% N)	21	8	-	100	170	-	-	-
Blended	21	8	-	100	200	-	-	-
Guncotton (13.3% N)	21	9	-	100	230	0.10	-	-
Nitroglycerin	7	16	100	100	222	-	-	-
Nitrostarch	36	-	-	-	217	-	-	-
PETN	43	17	5	100	215	0.03	0.17	0.036
TEGN	307	100+	0	-	225	-	-	-
TMETN	-	-	100	-	235	-	-	-
Nitramines								
HMX	-	32	100 (steel shoe) 0 (fiber shoe)	-	327	0.30	-	-
RDX	57	33	20	100	260	0.05	0.19	-
EDDN	64	75	-	-	445	-	2.0	
Haleite	-	48	0	-	190	0.21	0.13	
Nitroguanidine	-	47	0	0	275	0.20	-	-
Tetryl	57	26	0	70	257	0.10	0.19	-

Table A-1. Sensitivity Test Values of Explosives (Cont)

Material	Impact test with 2 kilogram weight PA APP (% TNT)	Impact test with 2 kilogram weight BM APP (% TNT)	Pendulum friction test, percent explosions	Rifle bullet test, percent explosions	Explosion temperature test, °C	Minimum detonating charge, gram of- lead azide	Minimum detonating charge, gram of- mercury fulminate	Electrostatic sensitivity, joules
Nitroaromatics								
Ammonium picrate	121	100+	0	30	318	-	0.85	-
DATB	200	-	-	-	-	-	-	-
HNS	50	-	-	-	-	-	-	-
TATB	79	-	-	-	520	0.30	-	-
TNT	-	-	0	0	475	0.26	0.24	0.06
Ammonium nitrate	221	100+	0	0	no explosion	-	-	-
Binary								
Amatol	93 to 100	-	0	0	254 to 300	-	-	-
Composition A3	125	-	0	0	250 to 280	0.25	0.22	-
Composition B	100	75	-	20	278	0.20	0.22	-
Composition C3	100	100+	0	40	260	-	-	-
Composition C4	>100	-	0	20	263 to 290	0.20	-	-
55/45 Ednatol	-	95	0	0	190	0.22	0.22	-
75/25 Octol	170	-	0	-	350	0.30	-	-
70/30 Octol	136	-	0	-	335	0.30	-	-
50/50 Pentolite	86	34	0	80	220	0.13	0.19	-
Picratol	100	100+	0	0	285	-	-	-
70/30 Tetrytol	78	28	0	-	320	0.22	0.23	-
Tritonal	71	73	0	60	470	0.30	-	-
Ternary								
Amatex 20	107 to 129	-	-	6	240	-	-	-
HBX-1	75	-	-	75	-	-	-	-
HBX-2	80	-	-	80	-	-	-	-
HTA-3	121	-	0	90	370	-	-	-
Minol-2	93	35	-	-	224 to 280	-	-	-
Torpex	50	75	-	100	260	-	0.18	-
Quanternary								
DBX	71	-	-	49	200	0.20	-	-

Table A-2. Effects of Explosives

Material	Brisance measured by—		Fragmentation of shell percent TNT	Copper cylinder compression test	Rate of detonation		Ballistic pendulum test percent TNT	Trauzl lead block test percent TNT	Relative blast effect, percent TNT	
	Sand test (% TNT)	Plate dent test percent TNT			At density	Meters per second			Pressure	Impulse
Primary explosives										
Lead azide (pure)	40	-	-	-	4.68	5,400	-	40	-	-
DLA	38	-	-	-	-	-	-	-	-	-
Mercury fulminate	27.3 to 59	-	-	-	4.17	5,400	-	37 to 50	-	-
Diazodinitrophenol	94 to 105	-	-	-	1.63	7,100	-	110	-	-
Lead styphnate (normal)	22 to 53	-	-	-	2.9	5,200	-	42	-	-
Tetracene	40 to 70	-	-	-	-	-	-	51 to 63	-	-
Potassium dinitrobenzofuroxane	93	-	-	-	-	-	-	-	-	-
Aliphatic nitrate esters										
BTN	103	-	-	-	-	-	-	-	-	-
DEGN	100	-	-	-	1.38	6,760	127	144 to 150	-	-
Nitrocellulose										
Pyrocellulose (12.75% N)	94	-	-	-	-	-	-	-	-	-
Blended (13.3% N)	99	-	-	-	-	-	-	-	-	-
Guncotton	102	-	-	84	1.3	7,300	125	136 to 147	-	-
High nitrogen	108-120	-	-	-	-	-	-	-	-	-
Nitroglycerin	120	-	-	-	1.6	7,700	140	185	-	-
Nitrostarch(13.4% N)	-	-	-	83	0.90	6,190	145	-	-	-
PETN	129 to 141	127	-	-	1.773	8,300	145	170	-	-
TEGN	30.6	-	-	-	1.33	2,000	-	-	-	-
TMETN	91	-	-	-	-	-	-	140	-	-
Nitramines										
HMX	125	-	-	-	1.89	9,110	170	159 to 165	-	-
RDX	125 to 145	135 to 141	141	-	1.770	8,700	150	170	-	-
EDDN	96	100	-	-	1.50	6,915	120	125	-	-

Table A-2. Effects of Explosives (Cont)

Material	Brisance measured by—		Fragmentation of shell percent TNT	Copper cylinder compression test	Rate of detonation		Ballistic pendulum test percent TNT	Trauzl lead block test percent TNT	Relative blast effect, percent TNT	
	Sand test (% TNT)	Plate dent test percent TNT			At density	Meters per second			Pressure	Impulse
Haleite	109 to 119	113 to 122	117 to 147	-	1.55	7,883	136	122 to 143	-	-
Nitroguanidine	73.5 to 84	95	-	-	1.70	8,100	104	78 to 101	-	-
Tetryl	113 to 123	115	121	117 to 125	1.71	7,850	145	125 to 145	-	-
Nitroaromatics										
Ammonium picrate	78 to 82.5	91	99	-	1.63	7,154	98	-	-	-
DATB	-	120	-	-	1.79	7,585	-	-	-	-
HNAB	-	-	-	-	1.77	7,250	-	123	-	-
HNS	-	120	-	-	1.70	7,000	-	-	-	-
TATB	90	-	-	-	1.937	8,000	-	-	-	-
TNT	-	-	-	-	1.636	6,826	-	-	-	-
Ammonium nitrate	-	-	-	-	1.0	2,800	-	75	-	-
Binary										
Amatol	74 to 94	-	81	-	1.6	5,300 to 6,550	122	116 to 126	97	87
Composition A3	107 to 115	126	150	-	1.6	8,200	132	144	-	-
Composition B	113	129 to 132	142	-	1.68	7,840	133	131	110	110
Composition C3	112	114 to 118	133	-	1.6	7,625	126	117	105	109
Composition C4	116	115 to 130	-	-	1.59	8,040	130	-	-	-
CH6	128	-	-	-	-	8,223	-	-	-	-
55/45 Ednatol	112	112	118	-	1.63	7,340	119	119	108	110
75/25 Octol	-	-	-	-	1.81	8,364 to 8,643	-	-	-	-
70/30 Octol	-	-	-	-	1.80	8,310 to 8,377	-	-	-	-
50/50 Pentolite	114	126	131	113	1.62	7,402	126	121	105	107
Picratol	94	100	102	-	1.67	6,970	100	-	100	100
70/30 Tetrytol	111	118	119	-	1.61	7,350	-	120	-	-
80/20 Tritonal	114	93	91	-	1.76	6,770	124	153	113	118

Table A-2. Effects of Explosives (Cont)

Material	Brisance measured by—		Fragmentation of shell percent TNT	Copper cylinder compression test	Rate of detonation		Ballistic pendulum test percent TNT	Trauzl lead block test percent TNT	Relative blast effect, percent TNT	
	Sand test (% TNT)	Plate dent test percent TNT			At density	Meters per second			Pressure	Impulse
Ternary										
Amatex 20	-	-	-	-	1.61	6,944	-	-	-	-
HBX-1	102	-	129	-	1.75	7,222	-	-	121	116
HBX-3	93.5	-	68	-	1.86	6,920	-	-	121	125
HTA-3	128	-	-	-	-	7,866	-	-	-	-
Minol-2	86	66	-	-	1.77	6,200	143	165	-	-
Torpex	122	120	126	-	1.8	7,660	134	161	122	125
Quanternary										
DBX	112	-	-	-	1.76	6,800	-	-	-	-

Table A-3. Thermochemical Characteristics of Explosives

Material	Heat of combustion, calories per gram at constant pressure	Heat of formation, kilogram calories per mole	Products of explosion: Heat, calories per gram (H_2O gas)	Products of explosion: Gas, milliliters per gram
Primary explosives				
Lead azide	-	−112 to −126.3	367	308
Mercury fulminate	938	−221 to −226	427	315
Diazodinitrophenol	-	956	820	-
Lead styphnate	1,251	92.3	460	440
Tetracene	-	270	658	1,190
Aliphatic nitrate esters				
BTN	2,167	368	1,458	-
DEGN	2,792	−99.4	1,161	-
Nitrocellulose				
Pyroxlyn (12% N)	-	−216	1,020	-
Guncotton (13.35% N)	2,313	−200	1,020	883.2
High nitrogen (14.14% N)	-	−191	1,810	-
Nitroglycerin	1,603	−90.8	1,486	715
PETN	1,957	−128.7	1,510	790
TEGN	3,428	−603.7	750	-
TMETN	2,642	−422	-	-
Nitramines				
HMX	2,231 to 2,253	11.3 to 17.93	1,460	-
RDX	2,259 to 2,264	14.71	1,460	908
EDDN	2,013	156.1	128 to 159	-
Haleite	2,477	20.11	1,276	908
Nitroguanidine	2,021	20.29	880	1,077
Tetryl	2,914	4.67 to 7.6	1,450	760
Nitroaromatics				
Ammonium picrate	2,745	95.82	800	-
DATB	-	−97.1 to −119	910	-
HNAB	-	−58 to −67.9	1,420	-
HNS	3,451	−13.9 to 1.87	1,360	-
TATB	2,850	−33.46 to −36.85	1,018	-
TNT	3,563 to 3,598	−10 to −19.99	1,290	730
Ammonium nitrate	-	88.6	381	980

Table A-4. Stability Test Values of Explosives

Material	75°C international test, percent loss in weight	100°C heat test, percent loss in weight in- 1st 48 hr	100°C heat test, percent loss in weight in- 2d 48 hr	Vacuum stability test Sample, gm	100°C ML	100°C HR	120°C ML	120°C HR	150°C ML	150°C HR
Primary explosives										
Lead azide										
DLA	-	0.34	0.39	1	0.32	40	0.48	40	-	-
SLA	-	0.08	0.16	-	-	-	-	-	-	-
PVA-LA	-	0.13	-	1	0.20	40	0.44	40	-	-
RD1333	-	0.30	0.30	1	-	-	0.43	40	-	-
Mercury fulminate	0.18	explodes								
Diazodinitrophenol	0.24	2.10	2.20	5	7.6	40	-	-	-	-
Lead styphnate (normal)	-	1.5	1.5	1	0.4	40	0.4	40	-	-
Tetracene	0.5	23.2	3.4	-	-	-	-	-	-	-
Potassium dinitrobenzofuroxane	0.03	0.05	-	-	-	-	-	-	-	-
Lead mononitroresorcinate	-	-	-	2.3	-	-	0.4	40	-	-
Aliphatic nitrate esters										
Nitrocellulose (12% N)	-	0.3	0	1	-	-	5.0	48	-	-
Nitroglycerin	-	3.5	3.5	1	11 +	16	-	-	-	-
PETN	0.02	0.1	0.0	5	0.5	40	11 +	40	-	-
TEGN	-	1.8	1.6	1	0.45	40	0.8 to 0.99	8	-	-
TMETN	-	2.5	1.8	-	-	-	-	-	-	-
Nitramines										
HMX	-	0.05	0.03	5	0.37	40	0.45	40	0.62	40
RDX	0.03	0.04	0	5	-	-	0.9	40	2.5	40
Haleite	0.01	0.2	0.3	5	0.5	48	1.5 to 2.4	48	11 +	-
Nitroguanidine	0.04	0.46	0.09	5	0.4	40	0.5	40	-	-
Tetryl	0.01	0.1	0.0	5	0.3	40	1.0	40	11 +	12
Nitroaromatics										
Ammonium picrate	0.12	0.1	0.1	5	0.2	40	0.4	40	0.4	40
DATB	-	-	-	1	-	-	0.03	48	-	-
HNS	-	>1	-	-	-	-	-	-	-	-
TATB	-	.17	-	-	-	-	-	-	-	-
TNT	0.04	0.1	0.1	5	0.1	40	0.4	40	0.7	40
Ammonium nitrate	0.0	0.1	0.0	5	0.3	40	0.3	40	0.3	40

Table A-4. Stability Test Values of Explosives (Cont)

Material	75°C international test, percent loss in weight	100°C heat test, percent loss in weight in-		Vacuum stability test						
					100°C		120°C		150°C	
		1st 48 hr	2d 48 hr	Sample, gm	ML	HR	ML	HR	ML	HR
Binary										
50/50 Amatol	-	-	-	5	0.3	40	1.0	40	-	-
Composition B	-	0.2	0.2	5	0.7	48	0.9	48	11 +	48
Composition C3	-	-	-	-	1.21	48	11 +	48	-	-
Composition C4	-	0.13	0.0	-	0.20	40	-	-	-	-
55/45 Ednatol	-	0.2	0.1	5	0.7	40	11 +	24	-	-
75/25 Octol	-	-	-	5	-	-	0.39 to 0.65	40	11	40
70/30 Octol	-	-	-	5	-	-	0.37 to 0.76	40	5.10	40
50/50 Pentolite	-	0.0	0.2	5	2.5	40	11 +	16	-	-
Picratol	0.0	0.0	0.05	5	0.4	40	0.7	40	0.7	40
70/30 Tetrytol	-	0.1	0.1	5	3.0	40	11 +	40	-	-
80/20 Tritonal	-	-	-	5	0.1	40	0.2	40	0.8	40
Ternary										
HBX-1	-	0.058	0.0	-	-	-	-	-	-	-
HBX-2	-	0.70	0.0	-	-	-	-	-	-	-
Minol-2	-	-	-	5	0.0	48	2.1	40	-	-
Torpex	-	0.0	0.10	5	0.2	40	1.5	40	11 +	16

Table A-5. Density Values of Explosives in Grams Per Milliliter

Material	Crystal or liquid	Pressure in kilopascals (pounds per square inch)							Cast
		20,685 (3,000)	34,475 (5,000)	68,450 (10,000)	103,425 (15,000)	137,900 (20,000)	206,850 (30,000)	275,800 (40,000)	
Primary explosives									
Lead azide (pure)	4.87	-	-	-	-	-	-	-	-
DLA	-	-	-	-	3.14	-	-	-	-
SLA	-	-	-	-	3.31	-	-	-	-
PVA-LA	-	-	-	-	3.81	-	-	-	-
Mercury fulminate	4.43	3.0	3.2	3.6	3.82	4.0	4.1	-	-
Diazodinitrophenol	1.63 to 1.65	1.14	-	-	-	-	-	-	-
Lead styphnate (normal)	3.02	-	-	-	-	-	-	-	-
Tetracene	1.7	1.05	-	-	-	-	-	-	-
Aliphatic nitrate esters									
BTN	1.520	-	-	-	-	-	-	-	-
DEGN	1.39	-	-	-	-	-	-	-	-
Nitroglycerin	1.596	-	-	-	-	-	-	-	-

Table A-5. Density Values of Explosives in Grams Per Milliliter (Cont)

Material	Crystal or liquid	Pressure in kilopascals (pounds per square inch)							
		20,685 (3,000)	34,475 (5,000)	68,450 (10,000)	103,425 (15,000)	137,900 (20,000)	206,850 (30,000)	275,800 (40,000)	Cast
PETN	1.778	1.37	1.575	1.638	-	1.71	1.725	1.74	-
TEGN	1.335	-	-	-	-	-	-	-	-
TMETN	1.47	-	-	-	-	-	-	-	-
Nitramines									
HMX	1.905	-	-	-	-	-	-	-	-
RDX	1.816	1.46	1.52	1.60	1.65	1.68	1.70	1.71	-
Haleite	1.66 to 1.77	-	1.28	1.38	1.44	1.49	-	-	-
Nitroguanidine	1.71	0.95	-	-	-	-	-	-	-
Tetryl	1.73	1.40	1.47	1.57	1.63	1.67	1.71	1.71	1.62
Nitroaromatics									
Ammonium picrate	1.717	1.33	1.41	1.47	1.51	1.53	1.56	1.57	
HNAB	1.79	-	-	-	-	-	-	-	-
TNT	1.654	1.34	1.40	1.47	1.52	1.55	1.59	1.59	-
Ammonium nitrate	1.64 to 1.75	-	-	-	-	-	-	-	-
Binary									
Composition A3	-	1.47	-	-	-	-	-	-	-
Composition B	-	-	-	-	-	-	-	-	1.68
55/45 Ednatol	-	-	-	-	-	-	-	-	1.62
75/25 Octol	1.832 to 1.843	-	-	-	-	-	-	-	1.800
70/30 Octol	1.819 to 1.822	-	-	-	-	-	-	-	1.790
50/50 Pentolite	-	-	-	-	-	-	-	-	1.63 to 1.67
Picratol	-	-	-	-	-	-	-	-	1.62
70/30 Tetrytol	-	-	-	-	-	-	-	-	1.60
80/20 Tritonal	-	-	-	-	-	-	-	-	1.73
Ternary									
HBX-1	-	-	-	-	-	-	-	-	1.76
HBX-3	-	-	-	-	-	-	-	-	1.882
Minol-2	-	-	-	-	-	-	-	-	1.62 to 1.74
Torpex	-	-	-	-	-	-	-	-	1.82
Quanternary									
DBX	-	-	-	-	-	-	-	-	1.61 to 1.74

Table A-6. Conversion Factors and Constants

Unit	Factor	Product
Inches	25.4	Millimeters
Millimeters	0.03937	Inches
Microns	0.001	Millimeters
Angstrom units	0.0000001	Millimeters
Square inches	645.16	Square millimeters
Square millimeters	0.00155	Square inches
Cubic inches	16.387	Milliliters
Milliliters	0.061025	Cubic inches
Cubic feet	0.028317	Cubic meters
Cubic feet	7.48	U.S. gallons
Cubic meters	35.315	Cubic feet
Liters	61.022	Cubic inches
Liters	0.264178	U.S. gallons
U.S. gallons	231.	Cubic inches
U.S. gallons	3.78533	Liters
U.S. gallons	8.337	Pounds water at 15°C
Kilograms	2.2046	Pounds
Pounds	453.59	Grams
Ounce	28.35	Grams
Calories	4.1855	International joules
Calories	0.0413	Liter-atmospheres
Kilogram-calories	3.9685	BTU's
BTU's	0.25198	Kilogram-calories
BTU per cubic foot	890.	Kilogram calories per cubic meter
Kilograms per square centimeter	14.223	Pounds per square inch
Atmospheres	1033.3	Grams per square centimeter
Atmospheres	14.696	Pounds per square inch
Atmospheres	760.	Millimeters of mercury
Pounds per square inch	6.895	Kilopascals
Gram moles	22.414	Liters at 0°C and 760 mm of mercury
R (gas constant)	1.9684	Calories per °C per mole
Foot candles	1.	Lumens per square foot
Lumens	0.001496	Watts

Table A-7. Specifications[1]

Material	Specification Number
Primary explosives	
Lead azide	MIL-L-3055
Special purpose lead azide	MIL-L-14758
RD1333 (lead azide)	MIL-L-46225
Mercury fulminate	JAN-M-219
Diazodinitrophenol	JAN-D-552
Lead styphnate, basic	MIL-L-16355
Lead styphnate, normal	MIL-L-757
Tetracene	MIL-T-46938
Potassium dinitrobenzofuroxane	MIL-P-50486
Lead mononitroresorcinate	MIL-L-46496
Aliphatic nitrate esters	
Butanetriol trinitrate	no specification
Diethyleneglycol dinitrate	no specification
Nitrocellulose	MIL-N-244
Nitroglycerin	MIL-N-246
Nitrostarch	no specification
PETN	MIL-P-387
TEGN	no specification
TMETN	no specification
Nitramines	
HMX	MIL-H-45444
RDX	MIL-R-398
EDDN	no specification
Haleite	no specification
NQ	MIL-N-494
Tetryl	MIL-T-339
Nitroaromatics	
Ammonium picrate	MIL-A-166
DATB	no specification
HNAB	no specification
HNS	no specification
TATB	no specification
TNT	MIL-T-248
Ammonium nitrate	MIL-A-50460
Binary	
Amatol	no specification
Composition A3	MIL-C-440
Composition A4	MIL-C-440
Composition A5	MIL-E-14970
Composition A6	MIL-C-60051
Composition B	MIL-C-401
Composition B3	MIL-C-45113
Composition B4	MIL-C-46652
Cyclotol	MIL-C-13477
Composition CH6	MIL-C-21723

Table A-7. Specifications[1] (Cont)

Material	Specification Number
Ednatol	no specification
Octol	MIL-O-45445
Pentolite (50/50)	JAN-P-408
Picratols	no specification
Tetrytols	no specification
Tritonal	no specification
Ternary	
Amatex	no specification
Ammonal	no specification
H6	MIL-E-22267
HBX	MIL-E-22267
HTA-3	no specification
Minol-2	MIL-M-14745
Torpex	no specification
PBX	
Military specifications	
LX-14-0	MIL-H-46358
PBX Type 1	MIL-P-14999
PBX Type 2	
PBX 0280	MIL-R-48878
PBX 9010	MIL-P-45447
PBX 9407	MIL-R-63419
PBXN-203	MIL-E-85113
PBXN-4	MIL-P-23625
PBXN-5	MIL-E-81111
Navy specifications (ternary catagory)	
PBXN-3	OS-11641
PBXN-6	WS-12604
PBXN-101	WS-3829
PBXN-102	WS-3823
PBXN-103	OS-12800D
PBXN-104	WS-11511
PBXN-201	WS-11498
PBXN-301	WS-12612
Dept of energy specifications (Lawrence Livermore Laboratory [LLNL])	
LX-04	RM 252353
LX-07	RM 253379
LX-09	RM 253200
LX-10	RM 253511
LX-13	RM 253520

[1]Currently, because of worker exposure hazards, benzene is being replaced by other solvents in all specifications.

Table A-8. Hazardous Component Safety Data Sheet (HCSDS) Numbers

Material	Sheet Number
Amatex	00920
Amatol	00774
Ammonium nitrate	00252
Ammonium picrate	00905
Black powder	00020
Colored smoke (green, yellow, red, violet)	20016
Composition A3	00150
Composition A4	00311
Composition A5	00546
Composition A7	00910
Composition B	00101, 01276, 01277
Composition B4	00151
Composition B5	00413
Composition C4	00077
Composition CH6	00628
Composition H6	00829
Composition HTA-3	00630
DATB	01194
Diazodinitrophenol	40066
Dinitrotoluene	00439
Lead azide (CLA and PVA-LA)	00066
Lead azide RD1333	00128
LX14	01043
Military dynamite	00147
Nitrocellulose	00031
Nitroglycerin	00030
Nitroguanidine	00491
Nitrostarch	40067
Octol	00154
PBXN4	01195
PBXN5	00622
PBXN6	00994
50/50 Pentolite	00253
PETN	00087
Propellant M1	00447
Propellant M2	00807
Propellant M5	00317
Propellant M6	00371
Propellant M7	00221
Propellant M8	00238
Propellant M9	00035
Propellant M10	00601
Propellant M15	00822
Propellant M17	00823
Propellant M30	00318
Pyroxlyn	00860
Tetryl	00116
TMETN	01193
80/20 Tritonal	00479

APPENDIX B
BIBLIOGRAPHY

Army Material Command Pamphlet (AMCP) 706-180: (Engineering Design Handbook) Principles of Explosive Behavior. Washington, DC: Headquarters, US Army Material Command, 1972.

Army Material Command Pamphlet (AMCP) 706-185: (Engineering Design Handbook) Military Pyrotechnics: Part One, Theory and Application. Washington DC: Headquarters, US Army Material Command, 1967.

Army Material Command Pamphlet (AMCP) 706-186: (Engineering Design Handbook) Military Pyrotechnics: Part Two, Safety, Procedures, and Glossary. Washington, DC: Headquarters, US Army Material Command, 1963.

Army Material Command Pamphlet (AMCP) 706-188: (Engineering Design Handbook) Military Pyrotechnics: Part Four, Design of Ammunition of Pyrotechnic Effect. Washington, DC: Headquarters, US Army Material Command, 1974.

Brophy, Leo T., Wyndham D. Miles, and Rexmon Cochrane. *The Chemical Warfare Service, From Laboratory to Field.* US Army in World War II. Washington, DC: Office of Chief of Military History, Department of the Army, 1959.

Canby, Courtlandt. *A History of Weaponry.* New York: Hawthorne Books, Inc, 1963.

Davis, T.L. *Chemistry of Powder and Explosives.* New York, 1943.

DARCOM Regulation 385-100. Alexandria, Virginia: US Army Material Development and Readiness Command, 1981.

Dobratz, B.M. *LLNL Explosives Handbook: Properties of Chemical Explosives and Explosive Stimulants.* Springfield, Virginia: National Technical Information Service (US Department of Commerce), 1981.

Faber, Henry B. *The History and Development of Military Pyrotechnics.* Military Pyrotechnics, vol I. Washington, DC: Government Printing Office, 1919.

Fair, H. and R. Walker, ed. *Energetic Materials.* Technology of the Inorganic Azides, vol 2. New York: Plenum Press, 1977.

Green, Constance M., Harry C. Thompson, and Peter C. Roots. *The Ordnance Department, Planning Munitions for War.* US Army in World War II. Washington, DC: Office of Chief of Military History, Department of the Army, 1955.

Hermes, Walter G. *US Army in the Korean War, Truce Tent and Fighting Front.* Washington, DC: Office of the Chief of Military History, Department of the Army, 1966.

Joint Service Safety and Performance Manual for Qualification of Explosives for Military Use. Army Research and Development Command (ARRADCOM), 1972.

LASL Explosive Property Data. T. Gibbs and A. Popolato, editors, Berkeley: University of California Press, 1980.

Linder, V. *Explosives and Propellants.* Encyclopedia of Chemical Technology, Third Edition, vol 9. New York: John Wiley and Sons, 1980.

McLain, J.H. *Pyrotechnics.* Philadelphia: Franklin Institute Press, 1980.

Meyer, R. *Explosives.* Verlag Chemie, Weinheim, New York, 1977.

Military Chemistry and Chemical Compounds, FM 3-9/AFR 3557, 30 October, 1975.

Mitchell, William A. *World's Military History.* Harrisburg, PA: Military Service Publishing Co., 1935 (1921).

Partington, J.R. *A History of Greek Fire and Gunpowder. Cambridge, England: W. Heffer and Sons, LTD, 1960.*

Pollard, F.B. and J.H. Arnold, ed. Aerospace Ordnance Handbook. Englewood Cliffs, New Jersey: Prentiss Hall, 1966.

Prentiss, Agustin M. *Chemicals in War.* York, Pa: McGraw-Hill, Maple Press, 1937.

Pristera, F. *Explosives.* Encyclopedia of Industrial Chemical Analysis, vol 12. New York: John Wiley and Sons, 1971.

Stiefel, Ludwig. *Gun Propellants.* Progress in Astronautics and Aeronautics, vol 66, 1978.

The Encyclopedia of Explosives and Related Items. Springfield, Virginia: National Technical Information Service (US Department of Commerce), 1960-1982.

Thompson, Harry C. and Lida Mayo. *The Ordnance Department, Procurement and Supply.* US Army in World War II. Washington, DC: Office of Chief of Military History, Department of the Army, 1956.

Wells, H.G. *The Outline of History.* New York: The Macmillan Co., 1923 (1920).

Yinon, J. and S. Zitrin. *The Analysis of Explosives.* Peragamon Series in Analytical Chemistry, vol 3. New York: Peragamon Press, 1981.

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GLOSSARY OF TERMS

Anomaly. Any identified subsurface mass that may be geologic in origin, unexploded ordnance (UXO), or some other man-made material. Such identification is made through geophysical investigation and reflects the response of the sensor used to conduct the investigation.

Anomaly reacquisition. The process of confirming the location of an anomaly after the initial geophysical mapping conducted on a range. The most accurate reacquisition is accomplished using the same instrument used in the geophysical survey to pinpoint the anomaly and reduce the area the excavation team needs to search to find the item.[1]

Archives search report. An investigation to report past ordnance and explosives (OE) activities conducted on an installation.[2]

Arming device. A device designed to perform the electrical and/or mechanical alignment necessary to initiate an explosive train.

Blast overpressure. The pressure, exceeding the ambient pressure, manifested in the shock wave of an explosion.[6]

Blow-in-place. Method used to destroy UXO, by use of explosives, in the location the item is encountered.

Buried munitions. Munitions that have been intentionally discarded by being buried with the intent of disposal. Such munitions may be either used or unused military munitions. Such munitions do not include unexploded ordnance that become buried through use.

Caliber. The diameter of a projectile or the diameter of the bore of a gun or launching tube. Caliber is usually expressed in millimeters or inches. In some instances (primarily with naval ordnance), caliber is also used as a measure of the length of a weapon's barrel. For example, the term "5 inch 38 caliber" describes ordnance used in a 5-inch gun with a barrel length that is 38 times the diameter of the bore.[5]

Casing. The fabricated outer part of ordnance designed to hold an explosive charge and the mechanism required to detonate this charge.

Chemical warfare agent. A substance that is intended for military use with lethal or incapacitating effects upon personnel through its chemical properties.[3]

Clearance. The removal of UXO from the surface or subsurface at active and inactive ranges.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLA, commonly known as Superfund, is a Federal law that provides for the cleanup of releases from abandoned waste sites that contain hazardous substances, pollutants, and contaminants.[5]

Defense Sites. Locations that are or were owned by, leased to, or otherwise possessed or used by the Department of Defense. The term does not include any operational range, operating storage or manufacturing facility, or facility that is used for or was permitted for the treatment or disposal of military munitions.

Deflagration. A rapid chemical reaction occurring at a rate of less than 3,300 feet per second in which the output of heat is enough to enable the reaction to proceed and be accelerated without input of heat from another source. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction, and temperature, and may cause transition into a detonation.[6]

Demilitarization. The act of disassembling chemical or conventional military munitions for the purpose of recycling, reclamation, or reuse of components. Also, rendering chemical or conventional military munitions innocuous or ineffectual for military use. The term encompasses various approved demilitarization methods such as mutilation, alteration, or destruction to prevent further use for its originally intended military purpose.[8]

Department of Defense Explosives Safety Board (DDESB). The DoD organization charged with promulgation of ammunition and explosives safety policy and standards, and with reporting on the effectiveness of the implementation of such policy and standards.[6]

Detonation. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium. The rate of a detonation is supersonic, above 3,300 feet per second.[3]

Discarded Military Munitions (DMM). Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of consistent with applicable environmental laws and regulations 10 U.S.C. 2710 (e)(2).[14]

Disposal. The discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwaters.[7]

Dud-fired. Munitions that failed to function as intended or as designed. They can be armed or not armed as intended or at some stage in between.

Electromagnetic induction. Transfer of electrical power from one circuit to another by varying the magnetic linkage.

Excavation of anomalies. The excavation, identification, and proper disposition of a subsurface anomaly.[1]

Explosion. A chemical reaction of any chemical compound or mechanical mixture that, when initiated, undergoes a very rapid combustion or decomposition, releasing large volumes of highly heated gases that exert pressure on the surrounding medium. Also, a mechanical reaction in which failure of the container causes sudden release of pressure from within a pressure vessel. Depending on the rate of energy release, an explosion can be categorized as a deflagration, a detonation, or pressure rupture.[3]

Explosive. A substance or mixture of substances, which is capable, by chemical reaction, of producing gas at such a temperature, pressure and rate as to be capable of causing damage to the surroundings.

Explosive filler. The energetic compound or mixture inside a munitions item.

Explosive ordnance disposal (EOD). The detection, identification, field evaluation, rendering-safe recovery, and final disposal of unexploded ordnance or munitions. It may also include the rendering-safe and/or disposal of explosive ordnance that has become hazardous by damage or deterioration, when the disposal of such explosive ordnance is beyond the capabilities of the personnel normally assigned the responsibilities for routine disposal. EOD activities are performed by active duty military personnel.[9]

EOD incident. The suspected or detected presence of a UXO or damaged military munition that constitutes a hazard to operations, installations, personnel, or material. Each EOD response to a reported UXO is an EOD incident. Not included are accidental arming or other conditions that develop during the manufacture of high explosives material, technical service assembly operations, or the laying of land mines or demolition charges.

Explosive soil. Explosive soil refers to any mixture of explosives in soil, sand, clay, or other solid media at concentrations such that the mixture itself is reactive or ignitable. The concentration of a particular explosive in soil necessary to present an explosion hazard depends on whether the explosive is classified as "primary" or "secondary." Guidance on whether an explosive is classified as "primary" or "secondary" can be obtained from Chapters 7 and 8 of TM 9-1300-214, Military Explosives.[2]

Explosive train. The arrangement of different explosives in munitions arranged according to the most sensitive and least powerful to the least sensitive and most powerful (initiator - booster - burster). A small quantify of an initiating compound or mixture, such as lead azide, is used to detonate a larger quantity of a booster compound, such as tetryl, that results in the main or booster charge of a RDX composition, TNT, or other compound or mixture detonating.

Explosives safety. A condition in which operational capability, personnel, property, and the environment are protected from the unacceptable effects of an ammunition or explosives mishap.[7]

Explosives Safety Submission. The document that serves as the specifications for conducting work activities at the project. It details the scope of the project, the planned work activities and potential hazards, and the methods for their control.[2] It is prepared, submitted, and approved per DDESB requirements. It is required for all response actions that deal with energetic material (e.g., UXO, buried munitions), including time-critical removal actions, non-time-critical removal actions, and remedial actions involving explosive hazards.

False alarm. The incorrect classification of nonordnance (e.g., clutter) as ordnance, or a declared geophysical target location that does not correspond to the actual target location.

False negative. The incorrect declaration of an ordnance item as nonordnance by the geophysical instrument used, or such misidentification in post-processing; this results in potential risks remaining following UXO investigations.

False positive. When the geophysical sensor indicates an anomaly and nothing is found that cause the instrument to detect the anomaly.

Federal land manager. With respect to any lands owned by the United States Government, the secretary of the department with authority over such lands.

Formerly Used Defense Site (FUDS). Real property that was formerly owned by, leased by, possessed by, or otherwise under the jurisdiction of the Secretary of Defense or the components, including organizations that predate DoD.[2]

Fragmentation. The breaking up of the confining material of a chemical compound or mechanical mixture when an explosion occurs. Fragments may be complete items, subassemblies, or pieces thereof, or pieces of equipment or buildings containing the items.[3]

Fuze. 1. A device with explosive components designed to initiate a train of fire or detonation in ordnance. 2. A nonexplosive device designed to initiate an explosion in ordnance.[4]

Gradiometer. Magnetometer for measuring the rate of change of a magnetic field.

Ground-penetrating radar. A system that uses pulsed radio waves to penetrate the ground and measure the distance and direction of subsurface targets through radio waves that are reflected back to the system.

Hazard ranking system (HRS). The principal mechanism EPA uses to place waste sites on the National Priorities List (NPL). It is a numerically based screening system that uses information from initial, limited investigations — the preliminary assessment and the site inspection — to assess the relative potential of sites to pose a threat to human health or the environment.[5]

Hazardous substance. Any substance designated pursuant to Section 311(b)(2)(A) of the Clean Water Act (CWA); any element, compound, mixture, solution, or substance designated pursuant to Section 102 of CERCLA; any hazardous waste having the characteristics identified under or listed pursuant to Section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by an Act of Congress); any toxic pollutant listed under Section 307(a) of the CWA; any hazardous air pollutant listed under Section 112 of the Clean Air Act; and any imminently hazardous chemical substance or mixture with respect to which the EPA Administrator has taken action pursuant to Section 7 of the Toxic Substances Control Act.[10]

Hazardous waste. A solid waste, or combination of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may (a) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.[6] Chemical agents and munitions become hazardous wastes if (a) they become a solid waste under 40 CFR 266.202, and (b) they are listed as a hazardous waste or exhibit a hazardous waste characteristic; chemical agents and munitions that are hazardous wastes must be managed in accordance with all applicable requirements of RCRA.[11]

Ignitable soil. Any mixture of explosives in soil, sand, clay, or other solid media at concentrations such that the mixture itself exhibits any of the properties of ignitability as defined in 40 CFR 261.21.

Inactive range. A military range that is not currently being used, but that is still under military control and considered by the military to be a potential range area, and that has not been put to a new use that is incompatible with range activities.[11]

Incendiary. Any flammable material that is used as a filler in ordnance intended to destroy a target by fire.

Indian Tribe. Any Indian Tribe, band, nation, or other organized group or community, including any Alaska Native village but not including any Alaska Native regional or village corporation, which is recognized as eligible for the special programs and services provided by the United States to Indians because of their status as Indians.[10]

Inert. The state of some types of ordnance that have functioned as designed, leaving a harmless carrier, or ordnance manufactured without explosive, propellant, or pyrotechnic content to serve a specific training purpose. Inert ordnance poses no explosive hazard to personnel or material.[12]

Installation Restoration Program (IRP). A program within DoD that funds the identification, investigation, and cleanup of hazardous substances, pollutants, and contaminants associated with past DoD activities at operating and closing installations and at FUDS.

Institutional controls. Nonengineering measures designed to prevent or limit exposure to hazardous substances left in place at a site or to ensure effectiveness of the chosen remedy. Institutional controls are usually, but not always, legal controls, such as easements, restrictive covenants, and zoning ordinances.[13]

Land use controls. Any type of physical, legal, or administrative mechanism that restricts the use of, or limits access to, real property to prevent or reduce risks to human health and the environment.

Lead agency. The agency that provides the on-scene coordinator or remedial project manager to plan and implement response actions under the National Contingency Plan (NCP). EPA, the U.S. Coast Guard, another Federal agency, or a State – operating pursuant to a contract or cooperative agreement executed pursuant to Section 104(d)(1) of CERCLA, or designated pursuant to a Superfund Memorandum of Agreement (SMOA) entered into pursuant to subpart F of the NCP or other agreements – may be the lead agency for a response action. In the case of a release or a hazardous substance, pollutant, or contaminant, where the release is on, or the sole source of the release is from, any facility or vessel under the jurisdiction, custody or control of a Federal agency, that agency will be the lead agency.[5]

Magnetometer. An instrument for measuring the intensity of magnetic fields.

Maximum credible event. The worst single event that is likely to occur from a given quantity and disposition of ammunition and explosives. Used in hazards evaluation as a basis for effects calculations and casualty predictions.[2]

Military munitions. All ammunition products and components produced for or used by the armed forces for national defense and security, including ammunition products or components under the control of the Department of Defense, the Coast Guard, the Department of Energy, and the National Guard. The term includes confined gaseous, liquid, and solid propellants, explosives, pyrotechnics, chemical and riot control agents, chemical munitions, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges, and devices and components thereof.

The term does not include wholly inert items, improvised explosive devices, and nuclear weapons, nuclear devices, and nuclear components, other than non-nuclear components of nuclear devices that are managed under the nuclear weapons program of the Department of Energy after all required sanitization operations under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) have been completed (10 U.S.C. 101 (e)(4).[14]

Mishap. An accident or an unexpected event involving DoD ammunition and explosives.[7]

Most Probable Munition (MPM). For a Munitions Response Site (MRS) the MEC item that has the greatest hazard distance based on calculations of the explosion effects of the MEC items anticipated to be found at a site. Typically, the MPM is the MEC item with the greatest fragmentation or overpressure distance based on the type of munitions that were historically used at the site.[1]

Munitions constituents (MC). Any materials originating from unexploded ordnance, discarded military munitions, or other military munitions, including explosive and nonexplosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710 (e)(4)).[14] Munitions constituents may be subject to other statutory authorities, including but not limited to CERCLA (42 U.S.C. 9601 et seq.) and RCRA (42 U.S.C. 6901 et seq.).

Munitions and Explosives of Concern (MEC). This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks, means: (1) Unexploded ordnance (UXO); (2) Discarded military munitions (DMM); or (3) Munitions Constituents (e.g. TNT, RDX) present in high enough concentrations to pose an explosive hazard. Formerly known as Ordnance and Explosives (OE).[14]

Munitions response. Response actions, including investigation, removal and remedial actions to address the explosives safety, human health, or environmental risks presented by unexploded ordnance (UXO), discarded military munitions (DMM), or munitions constituents.[14] The term is consistent with the definitions of removal and remedial actions that are found in the National Contingency Plan. The response could be as simple as an administrative or legal controls that preserve a compatible land use (i.e., institutional controls) or as complicated as a long-term response action involving sophisticated technology, specialized expertise, and significant resources.

Munitions Response Area (MRA). Any area on a defense site that is known or suspected to contain UXO, DMM, or MC. Examples include former ranges and munitions burial areas. A munitions response area is comprised of one or more munitions response sites. An MRA is equivalent to a response area on a range that was formerly referred to as "closed, transferred or transferring" or CTT.[14]

Munitions Response Site (MRS). A discrete location within a MRA that is known to require a munitions response.[14]

National Oil and Hazardous Substances Pollution Contingency Plan, or National Contingency Plan (NCP). The regulations for responding to releases and threatened releases of hazardous substances, pollutants, or contaminants under CERCLA.[5]

National Priorities List (NPL). A national list of hazardous waste sites that have been assessed against the Hazard Ranking System and score above 28.5. The listing of a site on the NPL takes place under the authority of CERCLA and is published in the *Federal Register*.[5]

Obscurant. Man-made or naturally occurring particles suspended in the air that block or weaken the transmission of a particular part or parts of the electromagnetic spectrum.

On-scene coordinator (OSC). The Federal Official designated by EPA, DoD, or the U.S. Coast Guard or the official designated by the lead agency to coordinate and direct response actions. Also, the Federal official designated by EPA or the U.S. Coast Guard to coordinate and direct Federal responses under subpart D, or the official designated by the lead agency to coordinate and direct removal actions under subpart E of the NCP.[5]

Open burning. The combustion of any material without (1) control of combustion air, (2) containment of the combustion reaction in an enclosed device, (3) mixing for complete combustion, and (4) control of emission of the gaseous combustion products.[8]

Open detonation. A chemical process used for the treatment of unserviceable, obsolete, and/or waste munitions whereby an explosive donor charge initiates the munitions to be detonated.[8]

Operational range. A range that is under the jurisdiction, custody, or control of the Secretary of Defense and (A) that is used for range activities; or (B) although not currently being used for range activities, that is still considered by the Secretary to be a range and has not been put to a new use that is incompatible with range activities.[14]

Overpressure. The blast wave or sudden pressure increase resulting from a violent release of energy from a detonation in a gaseous medium.[9]

Practice ordnance. Ordnance manufactured to serve a training purpose. Practice ordnance generally does not carry a full payload. Practice ordnance may still contain explosive components such as spotting charges, bursters, and propulsion charges.[12]

Preliminary assessment (PA) and site inspection (SI). A PA/SI is a preliminary evaluation of the existence of a release or the potential for a release. The PA is a limited-scope investigation based on existing information. The SI is a limited-scope field investigation. The decision that no further action is needed or that further investigation is needed is based on information gathered from one or both types of investigation. The results of the PA/SI are used by DoD to determine if an area should be designated as a "site" under the Installation Restoration Program. EPA uses the information generated by a PA/SI to rank sites against Hazard Ranking System criteria and decide if the site should be proposed for listing on the NPL.

Projectile. An object projected by an applied force and continuing in motion by its own inertia, as mortar, small arms, and artillery projectiles. Also applied to rockets and to guided missiles.

Propellant. An agent such as an explosive powder or fuel that can be made to provide the necessary energy for propelling ordnance.

Quantity-distance (Q-D). The relationship between the quantity of explosive material and the distance separation between the explosive and people or structures. These relationships are based on levels of risk considered acceptable for protection from defined types of exposures. These are not absolute safe distances, but are relative protective or safe distances.[2]

Range. Means designated land and water areas set aside, managed, and used to research, develop, test and evaluate military munitions and explosives, other ordnance, or weapon systems, or to train military personnel in their use and handling. Ranges include firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, and buffer zones with restricted access and exclusionary areas. (40 CFR 266.601) A recent statutory change added Airspace areas designated for military use in accordance with regulations and procedures prescribed by the Administrator of the Federal Aviation Administration. (10 U.S.C. 101 (e)(3))

Reactive soil. Any mixture of explosives in soil, sand, clay, or other solid media at concentrations such that the mixture itself exhibits any of the properties of reactivity as defined in 40 CFR 261.23.

Real property. Land, buildings, structures, utility systems, improvements, and appurtenances thereto. Includes equipment attached to and made part of buildings and structures (such as heating systems) but not movable equipment (such as plant equipment).

Record of Decision (ROD). A public decision document for a Superfund site that explains the basis of the remedy decision and, if cleanup is required, which cleanup alternative will be used. It provides the legal record of the manner in which the selected remedy complies with the statutory and regulatory requirements of CERCLA and the NCP.[5]

Release. Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles containing any hazardous substance or pollutant or contaminant).[10]

Remedial action. A type of response action under CERCLA. Remedial actions are those actions consistent with a permanent remedy, instead of or in addition to removal actions, to prevent or minimize the release of hazardous substances into the environment.[10]

Remedial investigation and feasibility study (RI/FS). The process used under the remedial program to investigate a site, determine if action is needed, and select a remedy that (a) protects human health and the environment; (b) complies with the applicable or relevant and appropriate requirements; and (c) provides for a cost-effective, permanent remedy that treats the principal threat at the site to the maximum extent practicable. The RI serves as the mechanism for collecting data to determine if there is a potential risk to human health and the environment from releases or potential releases at the site. The FS is the mechanism for developing, screening, and evaluating alternative remedial actions against nine criteria outlined in the NCP that guide the remedy selection process.

Remedial project manager (RPM). The official designated by the lead agency to coordinate, monitor, and direct remedial or other response actions.[5]

Removal action. Short-term response actions under CERCLA that address immediate threats to public health and the environment.[10]

Render-safe procedures. The portion of EOD procedures involving the application of special EOD methods and tools to provide for the interruption of functions or separation of essential components of UXO to prevent an unacceptable detonation.[9]

Resource Conservation and Recovery Act (RCRA). The Federal statute that governs the management of all hazardous waste from cradle to grave. RCRA covers requirements regarding identification, management, and cleanup of waste, including (1) identification of when a waste is solid or hazardous; (2) management of waste — transportation, storage, treatment, and disposal; and (3) corrective action, including investigation and cleanup, of old solid waste management units.[6]

Response action. As defined in Section 101 of CERCLA, "remove, removal, remedy, or remedial action, including enforcement activities related thereto." As used in this handbook, the term response action incorporates cleanup activities undertaken under any statutory authority.[10]

Solid waste. Any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but not including solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges that are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act as amended, or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended.[6] When a military munition is identified as a solid waste is defined in 40 CFR 266.202.[11]

State. The several States of the United States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the Virgin Islands, the Commonwealth of Northern Marianas, and any other territory or possession over which the United States has jurisdiction. Includes Indian Tribes as defined in CERCLA Chapter 103 § 9671.[5]

Treatment. When used in conjunction with hazardous waste, means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste nonhazardous, safer for transport, amenable for recovery, amenable for storage, or reduced in volume. Such term includes any activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it nonhazardous.[6]

Unexploded ordnance (UXO). These Guidelines will use the term "UXO" as defined in the Military Munitions Rule. "UXO means military munitions that have been primed, fuzed, armed, or otherwise prepared for action, and have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installation, personnel, or material and that remain unexploded either by malfunction, design, or any other cause." This definition also covers all ordnance-related items (e.g., low-order fragments) existing on a non-operational range. (40 CFR Part 266.201, 62 FR 6654, February 12, 1997).[11]

Warhead. The payload section of a guided missile, rocket, or torpedo.

Sources:

1. Department of Defense. EM 1110-1-4009. June 23, 2000.
2. U.S. Army Corps of Engineers Pamphlet No. 1110-1-18, "Engineering and Design Ordnance and Explosives Response," April 24, 2000.
3. DoD 6055.9-STD, Department of Defense Ammunition and Explosives Safety Standards.
4. Federal Advisory Committee for the Development of Innovative Technologies, "Unexploded Ordnance (UXO): An Overview," Naval Explosive Ordnance Disposal Technology Division, UXO Countermeasures Department, October 1996.
5. National Oil and Hazardous Substances Pollution Contingency Plan (more commonly called the National Contingency Plan), 40 C.F.R. § 300 et seq.

6. Department of Defense Directive 6055.9. "DoD Explosives Safety Board (DDESB) and DoD Component Explosives Safety Responsibilities," July 29, 1996.
7. Resource Conservation and Recovery Act (RCRA), 42 U.S.C. § 6901 et seq.
8. Department of Defense. Policy to Implement the EPA's Military Munitions Rule. July 1, 1998.
9. Joint Publication 1-02, "DoD Dictionary of Military and Associated Terms," April 12, 2001.
10. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9601 et seq.
11. Military Munitions Rule: Hazardous Waste Identification and Management; Explosives Emergencies; Manifest Exception for Transport of Hazardous Waste on Right-of-Ways on Contiguous Properties, Final Rule, 40 C.F.R. § 260 et seq.
12. Former Fort Ord, California, Draft Ordnance Detection and Discrimination Study Work Plan, Sacramento District, U.S. Army Corps of Engineers. Prepared by Parsons. August 18, 1999.
13. EPA Federal Facilities Restoration and Reuse Office. *Institutional Controls and Transfer of Real Property Under CERCLA Section 120(h)(3)(A), (B), or (C)*, Interim Final Guidance, January 2000.
14. Department of Defense Memorandum,"Definitions Related to Munitions Response Actions," from the Office of the Under Secretary of Defense, December 18, 2003.

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ACRONYMS

ARAR	applicable or relevant and appropriate requirements
ATR	aided or automatic target recognition
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	autonomous tow vehicle
BIP	blow-in-place
BRAC	Base Realignment and Closure Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	conceptual site model
DDESB	Department of Defense Explosives Safety Board
DERP	Defense Environmental Restoration Program
DGPS	differential global positioning system
DMM	discarded military munitions
DoD	Department of Defense
DOE	Department of Energy
DQO	data quality objective
EMI	electromagnetic induction
EMR	electromagnetic radiation
EOD	explosive ordnance disposal
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESS	Explosives Safety Submission
FFA	Federal facility agreement
FFCA	Federal Facility Compliance Act
FUDS	Formerly Used Defense Sites
GIS	geographic information system
GPR	ground-penetrating radar
GPS	global positioning system
HMX	Her Majesty's Explosive, High Melting Explosive
IAG	interagency agreement
IR	infrared
IRIS	Integrated Risk Information System
JPGTD	Jefferson Proving Ground Technology Demonstration Program
JUXOCO	Joint UXO Coordination Office
MCE	maximum credible event
MEC	munitions and explosives of concern
MRA	munitions response area
MRS	munitions response site
MTADS	Multisensor Towed-Array Detection System
NCP	National Contingency Plan
NPL	National Priorities List
OB/OD	open burning/open detonation
PA/SI	preliminary assessment/site inspection
PEP	propellants, explosives, and pyrotechnics

PPE	personal protective equipment
PRG	preliminary remediation goal
QA/QC	quality assurance/quality control
Q-D	quantity-distance
RCRA	Resource Conservation and Recovery Act
RDX	Research Demolition Explosive
RF	radio frequency
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RSP	render-safe procedure
SAR	synthetic aperture radar
SARA	Superfund Amendments and Reauthorization Act
SERDP	Strategic Environmental Research and Development Program
TNT	2,4,6-Trinitrotoluene
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center
UWB	ultra wide band
UXO	unexploded ordnance

1.0 INTRODUCTION

1.1 Overview

This handbook has been written for regulators and the interested public to facilitate understanding of the wide variety of technical issues that surround the munitions response actions at current and former Department of Defense (DoD) facilities (see text box below). The handbook is designed to provide a common nomenclature to aid in the management of munitions and explosives of concern (MEC) which includes:

- Unexploded ordnance (UXO),
- Abandoned and/or buried munitions (discarded military munitions, or DMM), and
- Soil with properties that are reactive and/or ignitable due to contamination with munitions constituents.

The definition of MEC also includes facilities and equipment; however, the focus of this handbook is on the three items above.

The handbook also discusses common chemical residues (called munitions constituents) of explosives that may or may not retain reactive and/or ignitable properties but could have a potential impact on human health and the environment through a variety of pathways (surface and subsurface, soil, air and water).

Why Does This Handbook Focus on Munitions Response Areas/Sites?

EPA's major regulatory concern is MRAs that were former ranges and sites where the industrial activity may have ceased and MEC and munitions constituents may be present. This focus occurs for several reasons:

- MRAs are often either in or about to be in the public domain. EPA, States, Tribes, and local governments have regulatory responsibility at the Base Realignment and Closure Act (BRAC) facilities and the Formerly Used Defense Sites (FUDS) that represent a significant portion of those sites.
- EPA, States, Tribes, and local governments have encountered numerous instances where issues have been raised about whether former defense sites are safe for both their current use and the uses to which they may be put in the future.
- Ranges at active bases may have been taken out of service as a range and could be put to multiple uses in the future that may not be compatible with the former range use.
- The most likely sites where used and fired military munitions will be a regulated solid waste, and therefore a potential hazardous waste, are at defense sites that were formerly used as ranges.
- Other sites that are addressed by this handbook include nonrange defense sites where MEC may be encountered, such as scrap yards, disposal pits, ammunition plants, DoD ammunition depots, and research and testing facilities.
- Finally, EPA anticipates that the military will oversee and manage environmental releases at their active and inactive ranges and at permitted facilities as part of their compliance program.

For the purposes of simplifying the discussion, when the term **munitions and explosives of concern (MEC)** is used, the handbook is referring to the three groups listed above. When the handbook is referring to chemical residues that *may or may not* have reactive and/or ignitable characteristics, they are called **munitions constituents (MC)**.

Buried or stored bulk explosives are not often found at former ranges, but may be found at other MRSs (e.g., old manufacturing facilities). Although bulk explosives are not explicitly identified as a separate MEC item, the information in this handbook often applies to bulk explosives, as well as other MEC items.

The handbook is designed to facilitate a common understanding of the state of the art of MEC detection and munitions response, and to present U.S. Environmental Protection Agency (EPA) guidance on the management of munitions response actions. The handbook is currently organized into 10 chapters that are designed to be used as resources for regulators and the public. Each of the chapters presents basic information and defines key terms. The handbook is a living document and future revisions are likely. A number of areas covered by the handbook are the subject of substantial ongoing research and development and may change in the future (see text box below). Therefore, the handbook is presented in a notebook format so that replacement pages can be inserted as new technical information becomes available and as policies and procedures evolve. Replacement pages will be posted on the Federal Facilities Restoration and Reuse Office web page, a website of the Office of Solid Waste and Emergency Response (www.epa.gov/swerffrr).

Policy Background on Range Cleanup

The regulatory basis for MEC investigation and cleanup is evolving. This handbook has been prepared within the context of extensive discussion involving Congress, DoD, EPA, Federal land managers, States, Tribes, and the public about the cleanup and regulation of MRSs ranges.

1.2 The Common Nomenclature

Listed below are selected key terms that are necessary for understanding the scope of this handbook (see text box at right). For additional definitions, the user is directed to the glossary at the beginning of this document.

Changing Terminology

The terminology related to munitions and explosives of concern and related activities, is evolving. On December 18, 2003, the Department of Defense published a memorandum titled *Definitions Related to Munitions Response Actions*. The memorandum explained that these definitions are part of an evolving effort to implement a Military Munitions Response Program (MMRP) and are designed to "promote understanding, provide clarity, and consistency in both internal and external discussions." The most current terms and definitions from the Department of Defense are used in this publication. However, previously existing publications and references may use older terminology such as "ordnance and explosives (OE)" to refer to MEC and "closed, transferring, and transferred (CTT) ranges" to refer to ranges that are no longer operational. Titles of, and quotes from, these prior documents have not been changed. to reflect the new terms.

1. **Unexploded ordnance** — The term UXO, or unexploded ordnance, means military munitions that have been primed, fuzed, armed, or otherwise prepared for action, and have been fired, dropped, launched, projected, or placed in such a manner as to

constitute a hazard to operations, installations, personnel, or material and remain unexploded either by malfunction, design, or any other cause.

> **About These Definitions**
>
> The user of this handbook should be aware that the definitions below are not necessarily official or regulatory definitions. Instead, they are an attempt to "translate" the formal definition into "plain English." However, the glossary associated with this handbook uses official definitions when available. Those definitions that come from official sources (e.g., statutes, regulations, formal policy, or standards) are appropriately footnoted. The user should not rely on the definitions in this chapter or the glossary for legal understanding of a key term, but should instead refer to the promulgated and/or other official documents.

2. **Range** — The term "range," when used in a geographic sense, means a designated land or water area that is set aside, managed, and used for range activities of the Department of Defense. Such terms includes the following: (a) firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, electronic scoring lines, buffer zones with restricted access, and exclusionary areas; (b) airspace areas designated for military use in accordance with regulations and procedures prescribed by the administrator of the Federal Aviation Commission.

3. **Operational range —** A range that is under the jurisdiction, custody, or control of the Secretary of Defense and (a) that is used for range activities, or (b), although not currently used for range activities, that is still considered by the Secretary of Defense to be a range and has not been put to a new use that is incompatible with range activities.[16]

4. **Munitions and Explosives of Concern (MEC)** — This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks, means: (1) unexploded ordnance (UXO), (2) discarded military munitions (DMM) (e.g., buried munitions), or (3) munitions constituents (e.g., TNT, RDX) present in high enough concentrations to pose an explosive hazard. Formerly called ordnance and explosives (OE).[16]

5. **Munitions Response Area (MRA).** Any area on a defense site that is known or suspected to contain UXO, DMM, or MC. Examples include former ranges and munitions burial areas. A munitions response area is a large area where MEC may be known or suspected to be present. An MRA is typically comprised of one or more munitions response sites.

6. **Munitions Response Site (MRS).** A discrete location within a MRA that is known to require a munitions response.

7. **Discarded Military Munitions (DMM).** Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military

munitions that have been properly disposed of consistent with applicable environmental laws and regulations. It does include buried munitions that have been disposed of with or without authorization.

8. **Buried munitions** — Buried munitions are used or unused military munitions that have been intentionally discarded and buried under the land surface with the intent of disposal. The overarching term for buried munitions is discarded military munitions.

9. **Defense sites** — Locations that are or were owned by, leased to, or otherwise possessed or used by the Department of Defense. The term does not include any operational range, operating storage or manufacturing facility, or facility that is used for or was permitted for the treatment or disposal of military munitions.

10. **Explosive soil** — Soil is considered explosive when it contains concentrations of explosives or propellants such that an explosion hazard is present and the soil is reactive or ignitable.

11. **Munitions constituents** — This term refers to the chemical constituents of military munitions that remain in the environment, including (1) residuals of munitions that retain reactive and/or ignitable properties, and (2) chemical residuals of explosives that are not reactive and/or ignitable but may pose a potential threat to human health and the environment through their toxic properties.

12. **Anomaly** — The term is applied to any identified subsurface mass that may be geologic in origin, UXO, or some other man-made material. Such identification is made through geophysical investigations and reflects the response of the sensor used to conduct the investigation.

13. **Clearance** — The removal of UXO from the surface or subsurface at active and inactive ranges. This term used to be in widespread use at ranges that are no longer operational. Many published documents use this term when referring to removal of MEC at MRSs. The official term now used is Munitions Response (see below).

14. **Munitions response** — Response actions, including investigation and removal and remedial actions to address the explosives safety, human health, or environmental risks presented by UXO, discarded military munitions (DMM), or munitions constituents. The term is consistent with the definitions of removal and remedial actions that are found in the National Contingency Plan. The response could be as simple as administrative or legal controls that preserve a compatible land use (i.e., institutional controls) or as complicated as a long-term response action involving sophisticated technology, specialized expertise, and significant resources.

1.3 Organization of This Handbook

The remaining nine chapters of this handbook are organized as follows:

Chapter 2 — Regulatory Overview
Chapter 3 — Characteristics of Ordnance and Explosives
Chapter 4 — Detection of UXO and Buried Munitions
Chapter 5 — Response Technologies
Chapter 6 — Explosives Safety
Chapter 7 — Planning OE Investigations
Chapter 8 — Devising Investigation and Response Strategies
Chapter 9 — Underwater Ordnance and Explosives
Chapter 10 — Chemical Munitions and Agents

At the end of each chapter is a section titled "Sources and Resources." The information on those pages directs the reader to source material, websites, and contacts that may be helpful in providing additional information on subjects within the chapter. In addition, it documents some of the publications and materials used in the preparation of this handbook.

The handbook is organized in a notebook format because of the potential for change in a number of important areas, including the regulatory framework and detection and remediation technologies. Notes are used to indicate that a section is under development.

> **Warning**
>
> Unexploded ordnance poses a threat to life and safety. All areas suspected of having UXO should be considered unsafe, and potential UXO items should be considered dangerous. All UXO should be considered fuzed and capable of detonation. Only qualified UXO technicians or military explosive ordnance disposal (EOD) personnel should consider handling suspected or actual UXO. All entry into suspected UXO areas should be with qualified UXO technicians or EOD escorts.

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2.0 REGULATORY OVERVIEW

Munitions response actions are governed by numerous Federal, State, Tribal and local laws and may involve interaction among multiple regulatory and nonregulatory authorities.

On March 7, 2000, the U.S. Environmental Protection Agency and the Department of Defense entered into an interim final agreement to resolve some of the issues between the two agencies.[1] Some of the central management principles developed by DoD and EPA are quoted in the next text box. A number of other important issues are addressed by the principles, which are reprinted as an attachment to this chapter. Some of these will be referred to in other parts of this regulatory overview, as well as in other chapters of this handbook.

The discussion that follows describes the current regulatory framework for munitions response actions identifies issues that remain uncertain, and identifies specific areas of regulatory concern. The reader should be aware that interpretations may change and that final EPA and DoD policy guidance and/or regulations may alter some assumptions.

Key DoD/EPA Interim Final Management Principles

- The legal authorities that support site-specific munitions response actions include, but are not limited to: CERCLA, as delegated by Executive Order (EO 12580) and the National Oil and Hazardous Substances Pollution Contingency Plan (the National Contingency Plan, or NCP); the Defense Environmental Restoration Program (DERP); and the standards of the DoD Explosives Safety Board (DDESB).
- A process consistent with CERCLA and these management principles will be the preferred response mechanisms used to address MEC. This process is expected to meet any RCRA corrective action requirements.
- DoD will conduct munitions response actions when necessary to address explosives safety, human health, and the environment. DoD and the regulators must consider explosives safety in determining the appropriate response actions.
- DoD and EPA commit to the substantive involvement of States and Indian Tribes in all phases of the response process, and acknowledge that States and Indian Tribes may be the lead regulators in some cases.
- Public involvement in all phases of the response process is considered to be crucial to the effective implementation of a response.
- These principles do not affect Federal, State, and Tribal regulatory or enforcement powers or authority... nor do they expand or constrict the waiver of sovereign immunity by the United States in any environmental law.

Finally, it is not the purpose of this chapter to provide detailed regulatory analysis of issues that should be decided site-specifically. Instead, this chapter discusses the regulatory components of decisions and offers direction on where to obtain more information (see "Sources and Resources" at the end of this chapter).

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[1]DoD, Deputy Under Secretary of Defense for Environmental Security, and U.S. EPA Office of Solid Waste and Emergency Response. *Interim Final Management Principles for Implementing Response Actions at Closed, Transferring, and Transferred (CTT) Ranges*, March 7, 2000. These principles are provided in their entirety at the end of this chapter.

2.1 Regulatory Overview

As recognized in the DoD/EPA Interim Final Management Principles cited above and in EPA's draft MEC policy,[2] the principal regulatory programs that guide the cleanup of MRSs ranges include CERCLA, the Defense Environmental Restoration Program (DERP), and the requirements of the DoD Explosives Safety Board (DDESB). In addition, the principles assert a preference for cleanups that are consistent with CERCLA and the CERCLA response process. A number of other regulatory processes provide important requirements.

Federal, State, and Tribal laws applicable to off-site response actions (e.g., waste material removed from the contaminated site or facility), must be complied with. In addition, State regulatory agencies will frequently use their own hazardous waste authorities to assert their role in oversight of range investigation and cleanup. The RCRA program provides a particularly important regulatory framework for the management of munitions response actions. The substantive requirements of the Resource Conservation and Recovery Act (RCRA) must be achieved when response proceeds under CERCLA *and if* those requirements are either applicable, or relevant and appropriate (ARAR) to the site situation (see Section 2.1.4). Substantive requirements of other Federal, State and Tribal environmental laws must also be met when such laws are ARARs.

The following sections briefly describe the Federal regulatory programs that may be important in the management of munitions response actions.

> **Military Instructions**
>
> Each service has its own set of instructions on how to comply with environmental regulations. These are usually expressed as standards or regulations (e.g., Army uses AR 200-1 and 200-2 for environmental regulations). Some of the commonly referred to DoD regulations are listed in the "Sources and Resources" section of this chapter but are not discussed here.

2.1.1 Defense Environmental Restoration Program

Although the Department of Defense has been implementing its Installation Restoration Program since the mid-1970s, it was not until the passage of the Superfund Amendments and Reauthorization Act of 1986 (SARA), which amended CERCLA, that the program was formalized by statute. Section 211 of SARA established the Defense Environmental Restoration Program (DERP), to be carried out in consultation with the Administrator of EPA and the States (including Tribal authorities). In addition, State, Tribal, and local governments are to be given the opportunity to review and comment on response actions, except when emergency requirements make this unrealistic. The program has three goals:

1. Cleanup of contamination from hazardous substances, pollutants, and contaminants, consistent with CERCLA cleanup requirements as embodied in Section 120 of CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).
2. Correction of environmental damage, such as the detecting and disposing of unexploded ordnance, that creates an imminent and substantial endangerment to

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[2]EPA, Office of Solid Waste and Emergency Response, Federal Facilities Restoration and Reuse Office. *Policy for Addressing Ordnance and Explosives at Closed, Transferring, and Transferred Ranges and Other Sites*, July 16, 2001, Draft.

public health and the environment.

3. Demolition and removal of unsafe buildings and structures, including those at formerly used defense sites (FUDS).

2.1.2 CERCLA

CERCLA (otherwise known as Superfund) is an important Federal law that provides for the cleanup of releases of hazardous substances, pollutants, or contaminants. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300) provides the blueprint to implement CERCLA. Although the Federal Government (through EPA and/or the other Federal agencies) is responsible for implementation of CERCLA, the States, Federally recognized Tribal governments, and communities play a significant role in the law's implementation.

CERCLA (Section 104) authorizes a response when:

- There is a release or threat of a release of a hazardous substance into the environment, or
- There is a release or threat of a release into the environment of any pollutant or contaminant that may present an imminent and substantial danger to the public health or welfare.

The CERCLA process (described briefly below) examines the nature of the releases (or potential releases) to determine if there is an unacceptable threat to human health and the environment.

The principal investigation and cleanup processes implemented under CERCLA may involve removal or remedial actions. Generally, they involve the following:

1. **Removal actions** are time-sensitive actions often designed to address emergency problems or immediate concerns, or to put in place a temporary or permanent remedy to abate, prevent, minimize, stabilize, or mitigate a release or a threat of release.
2. **Remedial actions** are actions consistent with a permanent remedy, taken instead of or in addition to removal actions to prevent or minimize the release of hazardous substances. Remedial actions often provide for a more detailed and thorough evaluation of risks and response options than removal actions. In addition, remedial actions have as a specific goal attaining a remedy that "permanently reduces the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants."

Whether a removal or remedial action is undertaken is a site-specific determination. In either case, the process generally involves a number of steps, including timely assessment of whether a more comprehensive investigation is required, a detailed investigation of the site or area to determine if there is unacceptable risk, and identification of appropriate alternatives for cleanup, documentation of the decisions, and design and implementation of a remedy. As noted in the DoD and EPA Interim Final Management Principles, CERCLA response actions may include removal actions, remedial actions, or a combination of the two.

DoD/EPA Interim Final Management Principles Related to Response Actions

DoD components may conduct CERCLA response actions to address explosives safety hazards, to include UXO, at MRSs ranges per the NCP. Response activities may include removal actions, remedial actions, or a combination of the two.

For the most part, the CERCLA process is implemented at three kinds of sites:

- Sites placed on the National Priorities List (NPL) (both privately owned sites and those owned or operated by governmental entities). These are sites that have been assessed using a series of criteria, the application of which results in a numeric score. Those sites that score above 28.5 are proposed for inclusion on the NPL. The listing of a site on the NPL is a regulatory action that is published in the *Federal Register*. Both removal and remedial actions can be implemented at these sites.
- Private-party sites that are not placed on the NPL but are addressed under the removal program.[3]
- Non-NPL sites owned or controlled by Federal agencies (e.g., Department of Defense, Department of Energy). Both removal and remedial actions may be implemented at these sites. These sites generally are investigated and cleaned up in accordance with CERCLA.

Interim Final Management Principles and Response Actions

The Interim Final Management Principles signed by EPA and DoD make a number of statements that bring key elements of the Superfund program into a range cleanup program regardless of the authority under which it is conducted. Some of the more significant statements of principle are quoted here:

- Characterization plans seek to gather sufficient site-specific information to identify the location, extent, and type of any explosives safety hazards (particularly UXO), hazardous substances, pollutants or contaminants, and "other constituents"; identify the reasonably anticipated future land uses; and develop and evaluate effective response alternatives.
- In some cases, explosives safety, cost, and/or technical limitations may limit the ability to conduct a response and thereby limit the reasonably anticipated future land uses....
- DoD will incorporate any Technical Impracticability (TI) determinations and waiver decisions in appropriate decision documents and review those decisions periodically in coordination with regulators.
- Final land use controls for a given MRS will be considered as part of the development and evaluation of the response alternatives using the nine criteria established under CERCLA regulations (i.e., NCP)....This will ensure that any land use controls are chosen based on a detailed analysis of response alternatives and are not presumptively selected.
- DoD will conduct periodic reviews consistent with the Decision Document to ensure long-term effectiveness of the response, including any land use controls, and allow for evaluation of new technology for addressing technical impracticability determinations.

The authority to implement the CERCLA program is granted to the President of the United States. Executive Order 12580 (January 23, 1987) delegates most of the management of the program

[3]Generally, actions taken at private party sites that are not NPL sites are removal actions. However, in some cases, remedial response actions are taken at these sites as well.

to the Environmental Protection Agency. However, DoD, and the Department of Energy (DOE), and other Federal land managers (e.g., Department of Interior), are delegated response authority at their non-NPL facilities, for remedial actions and removal actions other than emergencies. They must still consult with Federal, State, and Tribal regulatory authorities, but make the "final" decision at their sites. DoD and DOE are delegated responsibility for response authorities at NPL facilities as well. When a DoD or DOE facility is on the NPL, however, under Section 120, EPA must concur with the Record of Decision (decision document).

Whether EPA concurrence is required or not, EPA and the States have substantial oversight responsibilities that are grounded in both the CERCLA and DERP statutes, such as the following:

- Extensive State and Tribal involvement in the removal and remedial programs is provided for (CERCLA Section 121(f)). A number of very specific provisions addressing State and Tribal involvement are contained in the NCP (particularly, but not exclusively, subpart F).
- Notification requirements apply to all removal actions, no matter what the time period. Whether or not the notification occurs before or after the removal is a function of time available and whether it is an emergency action. State, Tribal, and community involvement is related to the amount of time available before a removal action must start. If the removal action will not be completed within 4 months (120 days), then a community relations plan is to be developed and implemented. If the removal action is a non-time-critical removal action, and more than 6 months will pass before it will be initiated, issuance of the community relations plan, and review and comment on the proposed action, occurs before the action is initiated, (National Contingency Plan, 40 CFR 300.415).

In addition, DERP also explicitly discusses State involvement with regard to releases of hazardous substances:

- DoD is to promptly notify Regional EPA and appropriate State and local authorities of (1) the discovery of releases or threatened releases of hazardous substances and the extent of the threat to public health and the environment associated with the release, and (2) proposals made by DoD to carry out response actions at these sites, and of the start of any response action and the commencement of each distinct phase of such activities.
- DoD must ensure that EPA and appropriate State and local authorities are consulted (i.e., have an opportunity to review and comment) at these sites before taking response actions (unless emergency circumstances make such consultation impractical) (10 U.S.C. § 2705).

2.1.3 CERCLA Section 120

Section 120 of CERCLA is explicit as to the manner in which CERCLA requirements are to be carried out at Federal facilities. Specifically, Section 120 mandates the following:

- Federal agencies (including DoD) are subject to the requirements of CERCLA in the same manner as nongovernmental entities.

- The guidelines, regulations, and other criteria that are applicable to assessments, evaluations, and remedial actions by other entities apply also to Federal agencies.
- Federal agencies must comply with State laws governing removal and remedial actions to the same degree as private parties when such facilities are not included on the NPL.
- When the facility or site is on the NPL, an interagency agreement (IAG) is signed between EPA and the Federal agency to ensure expeditious cleanup of the facility. This IAG must be signed within 6 months of completion of EPA review of a remedial investigation/feasibility study (RI/FS) at the facility.
- When hazardous substances were stored for one or more years, and are known to have been released or disposed of, each deed transferring real property from the United States to another party must contain a covenant that warrants that all remedial actions necessary to protect human health and the environment with respect to any such [hazardous] substance remaining on the property have been taken (120(h)(3)).[4]
- Amendments to CERCLA (Section 120(h)(4)) through the Community Environmental Response Facilitation Act (CERFA, PL 102-426) require that EPA (for NPL installations) or the States (for non-NPL installations) concur with uncontaminated property determinations made by DoD.

2.1.4 Resource Conservation and Recovery Act (RCRA)

The Federal RCRA statute governs the management of all hazardous waste from generation to disposal, also referred to as "cradle to grave" management of hazardous waste. RCRA requirements include:

- Identification of when a material is a solid or hazardous waste
- Management of hazardous waste — transportation, storage, treatment, and disposal
- Corrective action, including investigation and cleanup, of solid waste management units at facilities that treat, store, or dispose of hazardous waste

The RCRA requirements are generally implemented by the States, which, once they adopt equivalent or more stringent standards, act through their own State permitting and enforcement processes in lieu of EPA's to implement the program. Thus, each State that is authorized to implement the RCRA requirements may have its own set of hazardous waste laws that must be considered.

When on-site responses are conducted under CERCLA, the substantive (as opposed to administrative) RCRA requirements may be considered to be either applicable, or relevant and appropriate, and must be complied with accordingly; however, DoD, the lead agency, need not obtain permits for on-site cleanup activities. Similarly, all substantive requirements of other Federal and State environmental laws that are ARARs must be met under CERCLA.

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[4]Under CERCLA §120(h)(3)(C), contaminated property may be transferred outside the Federal Government provided the responsible Federal agency makes certain assurances, including that the property is suitable for transfer and that the cleanup will be completed post-transfer.

The Federal Facility Compliance Act of 1992, or FFCA (PL 102-386), amended RCRA. FFCA required the EPA Administrator to identify when military munitions become hazardous wastes regulated under RCRA Subtitle C, and to provide for the safe transport and storage of such waste.

What Is a Military Munition?

According to the Military Munitions Rule, a military munition is all ammunition products and components produced or used by or for DoD or the U.S. Armed Services for national defense and security.

As required by the FFCA, EPA promulgated the Military Munitions Rule (62 FR 6622, February 12, 1997; the Munitions Rule), which identified when conventional and chemical military munitions become solid wastes, and therefore potentially hazardous wastes subject to the RCRA Subtitle C hazardous waste management requirements. Under the rule, routine range clearance activities – those directed at munitions used for their intended purpose at active and inactive ranges – are deemed to not render the used munition a regulated solid or potential hazardous waste. The phrase "used for their intended purpose" does not apply to on-range disposal (e.g., recovery, collection, *and* subsequent burial or placement in a landfill). Such waste will be considered a solid waste (and potential hazardous waste) when burial is not a result of a product use.

Unused munitions are not a solid or hazardous waste when being managed (e.g., stored or transported) in conjunction with their intended use. They may become regulated as a solid waste and potential hazardous waste under certain circumstances. An unused munition is not a solid waste or potential hazardous waste when it is being repaired, reused, recycled, reclaimed, disassembled, reconfigured, or otherwise subjected to materials recovery actions.

Unused Munitions Are a Solid (and Potentially Hazardous) Waste When They Are...

- Discarded and buried in an on-site landfill
- Destroyed through open burning and/or open detonation or some other form of treatment
- Deteriorated to the point where they cannot be used, repaired, or recycled or used for other purposes
- Removed from storage for the purposes of disposal
- Designated as solid waste by a military official

Finally, the Military Munitions Rule provides an exemption from RCRA procedures (e.g., permitting or manifesting) and substantive requirements (e.g., risk assessment for open burning/open detonation, Subpart X) in the response to an explosive or munitions emergency. The rule defines an explosive or munitions emergency as:

Used or Fired Munitions

Military munitions that (1) have been primed, fuzed, armed, or otherwise prepared for action *and* have been fired, dropped, launched, projected, placed, or otherwise used; (2) are munitions fragments (e.g., shrapnel, casings, fins, and other components that result from the use of military munitions); or (3) are malfunctions or misfires.

A situation involving the suspected or detected presence of unexploded ordnance (UXO), damaged or deteriorated explosives or munitions, an improvised explosive device (IED) or other potentially harmful chemical munitions or device that creates an actual or potential imminent threat to human health, including safety or the environment.

In general, the emergency situations described in this exemption parallel the CERCLA description of emergency removals — action must be taken in hours or days. However, the decision as to whether a permit exemption is required is made by an explosives or munitions emergency response specialist.

2.1.5 Department of Defense Explosives Safety Board (DDESB)

The DDESB was established by Congress in 1928 as a result of a major disaster at the Naval Ammunition Depot in Lake Denmark, New Jersey, in 1926. The accident caused heavy damage to the depot and surrounding areas and communities, killed 21 people, and seriously injured 51 others. The mission of the DDESB is to provide objective expert advice to the Secretary of Defense and the Service Secretaries on matters concerning explosives safety, as well as to prevent hazardous conditions for life and property, both on and off DoD installations, that result from the presence of explosives and the environmental effects of DoD munitions. The roles and responsibilities of the DDESB were expanded in 1996 with the issuance of DoD Directive 6055.9, on July 29, 1996. The directive gives DDESB responsibility for serving as the DoD advocate for resolving issues between explosives safety standards and environmental standards.

DDESB is responsible for promulgating safety requirements and overseeing their implementation throughout DoD. These requirements provide for extensive management of explosive materials, such as the following:

- Safe transportation and storage of munitions
- Safety standards for the handling of different kinds of munitions
- Safe clearance of real property that may be contaminated with munitions

Chapter 6 expands on and describes the roles and responsibilities of DDESB, as well as outlines its safety and real property requirements.

In addition to promulgating safety requirements, DDESB has established requirements for the submission, review, and approval of Explosives Safety Submissions for all DoD responses regarding UXO at FUDS and at BRAC facilities.

DoD/EPA Interim Final Management Principles Related to DDESB Standards

- In listing the legal authorities that support site-specific response actions, the management principles list CERCLA, DERP, and the DDESB together.
- With regard to response actions, in general the principles state that "DoD and the regulators must consider explosives safety in determining the appropriate response actions."
- Regarding response actions under CERCLA, the principles state that "Explosives Safety Submissions (ESS), prepared, submitted, and approved per DDESB requirements, are required for Time-Critical Removal Actions, Non-Time-Critical Removal Actions, and Remedial Actions involving explosives safety hazards, particularly UXO."

2.2 Conclusion

The regulatory framework for the management of munitions response actions is both complex and extensive. The DoD/EPA Interim Final Management Principles for Implementing Response Actions at Closed, Transferring, and Transferred (CTT) Ranges were a first step to providing guiding principles to the implementation of these requirements. EPA's own draft policy for addressing munitions and explosives of concern is another step. As DoD works with EPA, States, and Tribal organizations and other stakeholders to consider the appropriate nature of range regulation at MRSs, it is expected that the outlines of this framework will evolve further.

Dialogue will continue over the next few years on a number of important implementation issues, including many that are addressed in this handbook. For this reason, the handbook is presented in a notebook format. Sections of this handbook that become outdated can be updated with the new information.

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

Defense Science Board Task Force on Unexploded Ordnance. ***Report on Unexploded Ordnance (UXO) Clearance, Active Range UXO Clearance, and Explosive Ordnance Disposal (EOD) Programs***. Washington, DC: Department of Defense, Office of the Under Secretary of Defense for (Acquisition and Technology), Apr. 1998.

U.S. Department of Defense, Operation and Environmental Executive Steering Committee for Munitions (OEESCM). ***Munitions Action Plan: Maintaining Readiness through Environmental Stewardship and Enhancement of Explosives Safety in the Life Cycle Management of Munitions***. Nov. 2001.

U.S. Department of Defense and U.S. Environmental Protection Agency. ***Management Principles for Implementing Response Actions at Closed, Transferring, and Transferred (CTT) Ranges***. Interim final. Mar. 7, 2000.

U.S. EPA, Federal Facilities Restoration and Reuse Office. ***EPA Issues at Closed, Transferring, and Transferred Military Ranges***. Letter to the Deputy Under Secretary of Defense (Environmental Security), Apr. 22, 1999.

Information Sources

U.S. Department of Defense
Washington Headquarters Services
Directives and Records Branch (Directives Section)
http://www.dtic.mil/whs/directives

Department of Defense Environmental Cleanup (contains reports, policies, general publications, as well as extensive information about BRAC and community involvement)
http://www.dtic.mil/envirodod/index.html

Department of Defense Explosives Safety Board (DDESB)
2461 Eisenhower Avenue
Alexandria, VA 22331-0600
Fax: (703) 325-6227
http://www.ddesb.pentagon.mil

Department of Defense, Office of the Deputy Under Secretary of Defense (Installations and Environment, formerly Environmental Security)
http://www.acq.osd.mil/ens/

Environmental Protection Agency
Federal Facilities Restoration and Reuse Office
http://www.epa.gov/swerffrr/

Environmental Protection Agency
Office of Solid Waste
RCRA, Superfund, and EPCRA Hotline
Tel: (800) 424-9346 – Toll free
(703) 412-9810 – Metropolitan DC area and international calls, (800) 553-7672 – Toll free TDD
(703) 412-3323 – Metropolitan DC area and international TDD calls
http://www.epa.gov/epaoswer/hotline

U.S. Army Corps of Engineers
U.S. Army Engineering and Support Center
Ordnance and Explosives Mandatory Center of Expertise
P.O. Box 1600
4820 University Square
Huntsville, AL 35807-4301
http://www.hnd.usace.army.mil/

Guidance

U.S. Air Force. ***Environmental Restoration Programs***. Air Force Instruction (AFI) 32-7020, Feb. 7, 2001.

U.S. Air Force. ***Air Quality Compliance***. AFI 32-7040, May 9, 1994.

U.S. Air Force. ***Cultural Resources Management***. AFI 32-7065, June 13, 1994.

U.S. Air Force. ***Solid and Hazardous Waste Compliance***. AFI 32-7042, May 12, 1994.

U.S. Air Force. ***Water Quality Compliance***. AFI 32-7041, May 13, 1994.

U.S. Army. ***Cultural Resources Management***. AR 200-4, Oct. 1, 1998.

U.S. Army. ***Environmental Analysis of Army Actions***. Final Rule, 32 CFR Part 651; AR 200-2, Mar. 29, 2002.

U.S. Army. ***Environmental Protection and Enhancement***. AR 200-1, Feb. 21, 1997.

U.S. Army. ***Environmental Restoration Programs Guidance Manual***. Apr. 1998.

U.S. Army. ***Natural Resources – Land, Forest, and Wildlife Management***. AR 200-3, Feb. 28, 1995.

USACE (U.S. Army Corps of Engineers). ***Engineering and Design – Ordnance and Explosives Response***. EP 1110-1-18, Apr. 24, 2000.

USACE (U.S. Army Corps of Engineers). ***Engineering and Design – Ordnance and Explosives Response***. EM 1110-1-4009, June 23, 2000.

U.S. DoD (Department of Defense). ***Environmental Restoration Program***. Instruction 4715.7, Apr. 22, 1996.

U.S. DoD, Deputy Secretary of Defense. ***DoD Guidance on the Environmental Review Process to Reach a Finding of Suitability to Transfer (FOST) for Property Where Release or Disposal Has Occurred***; and ***DoD Guidance on the Environmental Review Process to Reach a Finding of Suitability to Transfer (FOST) for Property Where No Release or Disposal Has Occurred***. Memorandum of June 1, 1994, and guidance documents are available at URL: http://www.acq.osd.mil/installation/reinvest/manual/fosts.html.

U.S. DoD, Office of the Deputy Under Secretary of Defense (Installations and Environment). ***Management Guidance for the Defense Environmental Restoration Program***. Sept. 2001; URL: http://www.dtic.mil/envirodod/COffice/DERP_MGT_GUIDANCE_0901.pdf.

U.S. DoD, Office of the Under Secretary of Defense (Acquisition and Technology). ***DoD Policy on Responsibility for Additional Environmental Cleanup after Transfer of Real Property (25 July 1997)***. Available as attachments to *Base Reuse Implementation Manual*, DoD 4165.66-Mat (Appendix F, Part 2). URL: http://emissary.acq.osd.mil/oea/BRIM97.nsf/.

U.S. DoD and U.S. EPA. ***Environmental Site Closeout Process Guide***. Sept. 1999; available at EPA and DoD URLs: http://newweb.ead.anl.gov/ecorisk/closeout/docs/section1.pdf; also http://www.epa.gov/swerffrr/pdf/site_closeout.pdf.

U.S. EPA (U.S. Environmental Protection Agency). ***CERCLA Compliance with Other Laws Manual***. Washington, DC: U.S. EPA, Office of Solid Waste and Emergency Response; Interim Final, Part 1, Aug. 1988, EPA/540/G-89/006; Interim Final, Part 2, Aug. 1989, EPA/540/G-89/009.

U.S. EPA. ***EPA Guidance on the Transfer of Federal Property by Deed Before All Necessary Remedial Action Has Been Taken Pursuant to CERCLA Section 120(h)(3)*** (known as the Early Transfer Authority Guidance). June 16, 1998; available at URL: http://www.epa.gov/swerffrr/documents/hkfin.htm.

U.S. EPA, Office of Solid Waste and Emergency Response. ***Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA***. Aug. 1993; NTIS No. PB93-963422. An EPA fact sheet (EPA/540/F-94/009) on the guidance is available at URL: http://www.epa.gov/oerrpage/superfund/resources/remedy/pdf/540f-94009-s.pdf.

U.S. EPA. ***Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents*** (known as the ROD Guidance). July 1999; NTIS No. PB98-963241; EPA/540/R-98-031. Available at URL: http://www.epa.gov/superfund/resources/remedy/rods/.

U.S. EPA, Office of Solid Waste and Emergency Response (OSWER), Federal Facilities Restoration and Reuse Office (FFRRO). ***Guidelines for Addressing Ordnance and Explosives at Munitions Response Areas and other Sites***. Draft. July 10, 2002.

U.S. EPA. ***Institutional Controls and Transfer of Real Property Under CERCLA Section 120(h)(3)(A), (B) or (C)***. Feb. 2000. Available at URL: http://www.epa.gov/swerffrr/documents/fi-icops_106.htm.

U.S. EPA, Office of Emergency and Remedial Response. ***Use of Non-Time-Critical Removal Authority in Superfund Response Actions***. Memo from Steven Luftig, Director, OERR, Feb. 14, 2000; available at URL: http://www.epa.gov/superfund/resources/remedy/pdf/memofeb2000.pdf.

U.S. Marine Corps. ***Environmental Compliance and Protection Manual***. Directive P5090.2A, July 10, 1998.

U.S. Navy. ***Department of the Navy Cultural Resources Program***. SECNAV Instruction 4000.35, Apr. 9, 2001.

U.S. Navy. ***Environmental and Natural Resources Program Manual***. OPNAV Instruction 5090.1B, Nov. 1, 1994.

U.S. Navy. ***Environmental Protection Program for the Naval Supply Systems Command***. NAVSUP Instruction 5090.1, Nov. 1, 1994.

U.S. Navy. ***Evaluation of Environmental Effects from Department of the Navy Actions***. SECNAV Instruction 5090.6, July 26, 1991.

U.S. Navy. ***Storage & Handling of Hazardous Materials***. NAVSUP PUB 573, January 13, 1999.

<u>Statutes and Regulations</u>

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9601 et seq.

Defense Environmental Restoration Program (DERP), 10 U.S.C. § 2701-2708, 2810.

Department of Defense Ammunition and Explosives Safety Standards, DoD Directive 6055.9-STD, July 1999.

Department of Defense Explosives Safety Board, 10 U.S.C. § 172.

Military Munitions Rule: Hazardous Waste Identification and Management; Explosives Emergencies; Manifest Exception for Transport of Hazardous Waste on Right-of-Ways on Contiguous Properties; Final Rule, 40 C.F.R. § 260 et seq.

National Oil and Hazardous Substances Pollution Contingency Plan (more commonly called the National Contingency Plan), 40 C.F.R. § 300 et seq.

Resource Conservation and Recovery Act (RCRA), 42 U.S.C. § 6901 et seq.

Superfund Implementation, Executive Order (EO) 12580, Jan. 13, 1987; and EO 13016, amendment to EO 12580, Aug. 28, 1996.

DoD and EPA
Management Principles for Implementing Response Actions at Closed, Transferring, and Transferred (CTT) Ranges

Preamble

Many closed, transferring, and transferred (CTT) military ranges are now or soon will be in the public domain. DoD and EPA agree that human health, environmental and explosive safety concerns at these ranges need to be evaluated and addressed. On occasion, DoD, EPA and other stakeholders, however, have had differing views concerning what process should be followed in order to effectively address human health, environmental, and explosive safety concerns at CTT ranges. Active and inactive ranges are beyond the scope of these principles.

To address concerns regarding response actions at CTT ranges, DoD and EPA engaged in discussions between July 1999 and March 2000 to address specific policy and technical issues related to characterization and response actions at CTT ranges. The discussions resulted in the development of this Management Principles document, which sets forth areas of agreement between DoD and EPA on conducting response actions at CTT ranges.

These principles are intended to assist DoD personnel, regulators, Tribes, and other stakeholders to achieve a common approach to investigate and respond appropriately at CTT ranges.

General Principles

DoD is committed to promulgating the Range Rule as a framework for response actions at CTT military ranges. EPA is committed to assist in the development of this Rule. To address specific concerns with respect to response actions at CTT ranges prior to implementation of the Range Rule, DoD and EPA agree to the following management principles:

- DoD will conduct response actions on CTT ranges when necessary to address explosives safety, human health and the environment. DoD and the regulators must consider explosives safety in determining the appropriate response actions.

- DoD is committed to communicating information regarding explosives safety to the public and regulators to the maximum extent practicable.

- DoD and EPA agree to attempt to resolve issues at the lowest level. When necessary, issues may be raised to the appropriate Headquarters level. This agreement should not impede an emergency response.

- The legal authorities that support site-specific response actions at CTT ranges include, but are not limited to, the Comprehensive Environmental Response, Compensation, and Liability

Act (CERCLA), as delegated by Executive Order (E.O.) 12580 and the National Oil and Hazardous Substances Contingency Plan (NCP); the Defense Environmental Restoration Program (DERP); and the DoD Explosives Safety Board (DDESB).

- A process consistent with CERCLA and these management principles will be the preferred response mechanism used to address UXO at a CTT range. EPA and DoD further expect that where this process is followed, it would also meet any applicable RCRA corrective action requirements.

- These principles do not affect federal, state, and Tribal regulatory or enforcement powers or authority concerning hazardous waste, hazardous substances, pollutants or contaminants, including imminent and substantial endangerment authorities; nor do they expand or constrict the waiver of sovereign immunity by the United States contained in any environmental law.

1. State and Tribal Participation

DoD and EPA are fully committed to the substantive involvement of States and Indian Tribes throughout the response process at CTT ranges. In many cases, a State or Indian Tribe will be the lead regulator at a CTT range. In working with the State or Indian Tribe, DoD will provide them opportunities to:

- Participate in the response process, to the extent practicable, with the DoD Component.

- Participate in the development of project documents associated with the response process.

- Review and comment on draft project documents generated as part of investigations and response actions.

- Review records and reports.

2. Response Activities under CERCLA

DoD Components may conduct CERCLA response actions to address explosives safety hazards, to include UXO, on CTT military ranges per the NCP. Response activities may include removal actions, remedial actions, or a combination of the two.

- DoD may conduct response actions to address human health, environmental, and explosives safety concerns on CTT ranges. Under certain circumstances, other federal and state agencies may also conduct response actions on CTT ranges.

- Removal action alternatives will be evaluated under the criteria set forth in the National Contingency Plan (NCP), particularly NCP §300.410 and §300.415.

- DoD Components will notify regulators and other stakeholders, as soon as possible and to the extent practicable, prior to beginning a removal action.

- Regulators and other stakeholders will be provided an opportunity for timely consultation, review, and comment on all phases of a removal response, except in the case of an emergency response taken because of an imminent and substantial endangerment to human health and the environment and consultation would be impracticable (see 10 USC 2705).

- Explosives Safety Submissions (ESS), prepared, submitted, and approved per DDESB requirements, are required for Time Critical Removal Actions, Non-Time Critical Removal Actions, and Remedial Actions involving explosives safety hazards, particularly UXO.

- The DoD Component will make available to the regulators, National Response Team, or Regional Response Team, upon request, a complete report, consistent with NCP §300.165, on the removal operation and the actions taken.

- Removal actions shall, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action. If the DoD Component determines, in consultation with the regulators and based on these Management Principles and human health, environmental, and explosives safety concerns, that the removal action will not fully address the threat posed and remedial action may be required, the DoD Component will ensure an orderly transition from removal to remedial response activities.

3. Characterization and Response Selection

Adequate site characterization at each CTT military range is necessary to understand the conditions, make informed risk management decisions, and conduct effective response actions.

- Discussions with local land use planning authorities, local officials and the public, as appropriate, should be conducted as early as possible in the response process to determine the reasonably anticipated future land use(s). These discussions should be used to scope efforts to characterize the site, conduct risk assessments, and select the appropriate response(s).

- Characterization plans seek to gather sufficient site-specific information to: identify the location, extent, and type of any explosives safety hazards (particularly UXO), hazardous substances, pollutants or contaminants, and "Other Constituents"; identify the reasonably anticipated future land uses; and develop and evaluate effective response alternatives.

- Site characterization may be accomplished through a variety of methods, used individually or in concert with one another, including, but not limited to: records searches, site visits, or actual data acquisition, such as sampling. Statistical or other mathematical analyses (e.g., models) should recognize the assumptions imbedded within those analyses. Those assumptions, along with the intended use(s) of the analyses, should be communicated at the front end to the regulator(s) and the communities so the results may be better understood.

Statistical or other mathematical analyses should be updated to include actual site data as it becomes available.

- Site-specific data quality objectives (DQOs) and QA/QC approaches, developed through a process of close and meaningful cooperation among the various governmental departments and agencies involved at a given CTT military range, are necessary to define the nature, quality, and quantity of information required to characterize each CTT military range and to select appropriate response actions.

- A permanent record of the data gathered to characterize a site and a clear audit trail of pertinent data analysis and resulting decisions and actions are required. To the maximum extent practicable, the permanent record shall include sensor data that is digitally-recorded and geo-referenced. Exceptions to the collection of sensor data that is digitally-recorded and geo-referenced should be limited primarily to emergency response actions or cases where impracticable. The permanent record shall be included in the Administrative Record. Appropriate notification regarding the availability of this information shall be made.

- The most appropriate and effective detection technologies should be selected for each site. The performance of a technology should be assessed using the metrics and criteria for evaluating UXO detection technology described in Section 4.

- The criteria and process of selection of the most appropriate and effective technologies to characterize each CTT military range should be discussed with appropriate EPA, other Federal State, or Tribal agencies, local officials, and the public prior to the selection of a technology.

- In some cases, explosives safety, cost, and/or technical limitations, may limit the ability to conduct a response and thereby limit the reasonably anticipated future land uses. Where these factors come into play, they should be discussed with appropriate EPA, other federal, State or Tribal agencies, local officials, and members of the public and an adequate opportunity for timely review and comment should be provided. Where these factors affect a proposed response action, they should be adequately addressed in any response decision document. In these cases, the scope of characterization should be appropriate for the site conditions. Characterization planning should ensure that the cost of characterization does not become prohibitive or disproportionate to the potential benefits of more extensive characterization or further reductions in the uncertainty of the characterization.

- DoD will incorporate any Technical Impracticability (TI) determination and waiver decisions in appropriate decision documents and review those decisions periodically in coordination with regulators.

- Selection of site-specific response actions should consider risk plus other factors and meet appropriate internal and external requirements.

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4. UXO Technology

Advances in technology can provide a significant improvement to characterization at CTT ranges. This information will be shared with EPA and other stakeholders.

- The critical metrics for the evaluation of the performance of a detection technology are the probabilities of detection and false alarms. A UXO detection technology is most completely defined by a plot of the probability of detection versus the probability or rate of false alarms. The performance will depend on the technology's capabilities in relation to factors such as type and size of munitions, the munitions depth distribution, the extent of clutter, and other environmental factors (e.g., soil, terrain, temperature, geology, diurnal cycle, moisture, vegetation). The performance of a technology cannot be properly defined by its probability of detection without identifying the corresponding probability of false alarms. Identifying solely one of these measures yields an ill-defined capability. Of the two, probability of detection is a paramount consideration in selecting a UXO detection technology.

- Explosives safety is a paramount consideration in the decision to deploy a technology at a specific site.

- General trends and reasonable estimates can often be made based on demonstrated performance at other sites. As more tests and demonstrations are completed, transfer of performance information to new sites will become more reliable.

- Full project cost must be considered when evaluating a detection technology. Project cost includes, but is not limited to, the cost of deploying the technology, the cost of excavation resulting from the false alarm rate, and the costs associated with recurring reviews and inadequate detection.

- Rapid employment of the better performing, demonstrated technologies needs to occur.

- Research, development, and demonstration investments are required to improve detection, discrimination, recovery, identification, and destruction technologies.

5. Land Use Controls

Land use controls must be clearly defined, established in coordination with affected parties (e.g., in the case of FUDS, the current owner; in the case of BRAC property, the prospective transferee), and enforceable.

- Because of technical impracticability, inordinately high costs, and other reasons, complete clearance of CTT military ranges may not be possible to the degree that allows certain uses, especially unrestricted use. In almost all cases, land use controls will be necessary to ensure protection of human health and public safety.

- DoD shall provide timely notice to the appropriate regulatory agencies and prospective federal land managers of the intent to use Land Use Controls. Regulatory comments received during the development of draft documents will be incorporated into the final land use controls, as appropriate. For Base Realignment and Closure properties, any unresolved regulatory comments will be included as attachments to the Finding of Suitability to Transfer (FOST).

- Roles and responsibilities for monitoring, reporting and enforcing the restrictions must be clear to all affected parties.

- The land use controls must be enforceable.

- Land use controls (e.g., institutional controls, site access, and engineering controls) may be identified and implemented early in the response process to provide protectiveness until a final remedy has been selected for a CTT range.

- Land use controls must be clearly defined and set forth in a decision document.

- Final land use controls for a given CTT range will be considered as part of the development and evaluation of response alternatives using the nine criteria established under CERCLA regulations (i.e., NCP), supported by a site characterization adequate to evaluate the feasibility of reasonably anticipated future land uses. This will ensure that land use controls are chosen based on a detailed analysis of response alternatives and are not presumptively selected.

- DoD will conduct periodic reviews consistent with the Decision Document to ensure long-term effectiveness of the response, including any land use controls, and allow for evaluation of new technology for addressing technical impracticability determinations.

- When complete UXO clearance is not possible at military CTT ranges, DoD will notify the current land owners and appropriate local authority of the potential presence of an explosives safety hazard. DoD will work with the appropriate authority to implement additional land use controls where necessary.

6. Public Involvement

Public involvement in all phases of the CTT range response process is crucial to effective implementation of a response.

- In addition to being a requirement when taking response actions under CERCLA, public involvement in all phases of the range response process is crucial to effective implementation of a response.

- Agencies responsible for conducting and overseeing range response activities should take steps to proactively identify and address issues and concerns of all stakeholders in the process. These efforts should have the overall goal of ensuring that decisions made regarding response actions on CTT reflect a broad spectrum of stakeholder input.

- Meaningful stakeholder involvement should be considered as a cost of doing business that has the potential of efficiently determining and achieving acceptable goals.

- Public involvement programs related to management of response actions on CTT should be developed and implemented in accordance with DOD and EPA removal and remedial response community involvement policy and guidance.

7. Enforcement

Regulator oversight and involvement in all phases of CTT range investigations are crucial to an effective response, increase credibility of the response, and promote acceptance by the public. Such oversight and involvement includes timely coordination between DoD components and EPA, state, or Tribal regulators, and, where appropriate, the negotiation and execution of enforceable site-specific agreements.

- DoD and EPA agree that, in some instances, negotiated agreements under CERCLA and other authorities play a critical role in both setting priorities for range investigations and response and for providing a means to balance respective interdependent roles and responsibilities. When negotiated and executed in good faith, enforceable agreements provide a good vehicle for setting priorities and establishing a productive framework to achieve common goals. Where range investigations and responses are occurring, DoD and the regulator(s) should come together and attempt to reach a consensus on whether an enforceable agreement is appropriate. Examples of situations where an enforceable agreement might be desirable include locations where there is a high level of public concern and/or where there is significant risk. DoD and EPA are optimistic that field level agreement can be reached at most installations on the desirability of an enforceable agreement.

- To avoid, and where necessary to resolve, disputes concerning the investigations, assessments, or response at CTT ranges, the responsible DoD Component, EPA, state, and Tribe each should give substantial deference to the expertise of the other party.

- At NPL sites, disputes that cannot be mutually resolved at the field or project manager level should be elevated for disposition through the tiered process negotiated between DoD and EPA as part of the Agreement for the site, based upon the Model Federal Facility Agreement.

- At non-NPL sites where there are negotiated agreements, disputes that cannot be mutually resolved at the field or project manager level also should be elevated for disposition through a tiered process set forth in the site-specific agreement.

- To the extent feasible, conditions that might give rise to an explosives or munitions emergency (e.g., ordnance explosives) are to be set out in any workplan prepared in accordance with the requirements of any applicable agreement, and the appropriate responses to such conditions described, for example as has been done In the Matter of Former Nansemond Ordnance Depot Site, Suffolk, Virginia, Inter Agency Agreement to Perform a Time Critical Removal Action for Ordnance and Explosives Safety Hazards.

- Within any dispute resolution process, the parties will give great weight and deference to DoD's technical expertise on explosive safety issues.

8. Federal-to-Federal Transfers

DoD will involve current and prospective Federal land managers in addressing explosives safety hazards on CTT ranges, where appropriate.

- DoD may transfer land with potential explosives safety hazards to another federal authority for management purposes prior to completion of a response action, on condition that DoD provides notice of the potential presence of an explosives safety hazard and appropriate institutional controls will be in place upon transfer to ensure that human health and safety is protected.

- Generally, DoD should retain ownership or control of those areas at which DoD has not yet assessed or responded to potential explosives safety hazards.

9. Funding for Characterization and Response

DoD should seek adequate funding to characterize and respond to explosives safety hazards (particularly UXO) and other constituents at CTT ranges when necessary to address human health and the environment.

- Where currently identified CTT ranges are known to pose a threat to human health and the environment, DoD will apply appropriate resources to reduce risk.

- DoD is developing and will maintain an inventory of CTT ranges.

- DoD will maintain information on funding for UXO detection technology development, and current and planned response actions at CTT ranges.

10. Standards for Depths of Clearance

Per DoD 6055.9-STD, removal depths are determined by an evaluation of site-specific data and risk analysis based on the reasonably anticipated future land use.

- In the absence of site-specific data, a table of assessment depths is used for interim planning purposes until the required site-specific information is developed.

- Site specific data is necessary to determine the actual depth of clearance.

11. Other Constituent (OC) Hazards

CTT ranges will be investigated as appropriate to determine the nature and extent of Other Constituents contamination.

- Cleanup of other constituents at CTT ranges should meet applicable standards under appropriate environmental laws and explosives safety requirements.

- Responses to other constituents will be integrated with responses to military munitions, rather than requiring different responses under various other regulatory authorities.

References

A. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9601 et seq.

B. National Oil and Hazardous Substances Pollution Contingency Plan (more commonly called the National Contingency Plan), 40 C.F.R. § 300 et seq.

C. Resource Conservation and Recovery Act (RCRA), 42 U.S.C. § 6901 et seq.

D. Military Munitions Rule: Hazardous Waste Identification and Management; Explosives Emergencies; Manifest Exception for Transport of Hazardous Waste on Right-of-Ways on Contiguous Properties; Final Rule, 40 C.F.R. § 260, et al.

E. Defense Environmental Restoration Program, 10 U.S.C. § 2701-2708, 2810.

F. Department of Defense Explosives Safety Board, 10 U.S.C. § 172

G. Executive Order (E.O.) 12580, Superfund Implementation, January 13, 1987, and E.O. 13016, Amendment to Executive Order 12580, August 28, 1996.

H. DoD Ammunition and Explosives Safety Standards, DoD Directive 6055.9-STD, dated July 1999.

3.0 CHARACTERISTICS OF MUNITIONS AND EXPLOSIVES OF CONCERN

By their nature, munitions and explosives of concern (MEC), (including UXO, buried munitions, and reactive or ignitable soil) may present explosive, human health, and/or environmental risks. When disturbed, MEC may present an imminent hazard and can cause immediate death or disablement to those nearby. Different types of MEC vary in their likelihood of detonation. The explosive hazards depend upon the nature and condition of the explosive fillers and fuzes.

Nonexplosive risks from MEC result from the munitions' constituents and include both human health and environmental risks. As the munitions constituents of MEC come into contact with soils, groundwater, and air, they may affect humans and ecological receptors through a wide variety of pathways including, but not limited to, ingestion of groundwater, dermal exposure to soil, and various surface water pathways.

This chapter provides an overview of some of the information on MEC that you will want to consider when planning for an investigation of MEC. As will be discussed in Chapter 7, planning an investigation requires a careful and thorough examination of the actual use of munitions at the site that is under investigation. Many MRAs/MRSs were used for decades and had different missions that required the use of different types of munitions. Even careful archives searches will likely reveal knowledge gaps in how the ranges were used. This chapter provides basic information on munitions and factors that affect when they were used, where they may be found, and the human health and environmental concerns that may be associated with them. Information in this chapter provides an overview of:

- The history of explosives, chemicals used, and explosive functions.
- The nature of the hazards from conventional munitions and munitions constituents.
- The human health and environmental effects of munitions constituents that come from conventional munitions.
- Other activities that may result in releases of munitions constituents.

3.1 Overview of Explosives

In this section, the history of explosives in the United States, the nature of the explosive train, the different classifications of explosives and the kinds of chemicals associated with them is discussed.

3.1.1 <u>History of Explosives in the United States</u>

The following section presents only a brief summary of the history of explosives in the United States. Its purpose is to provide an overview of the types of explosive materials and chemicals in use during different time periods. This overview may be used in determining the potential types of explosives that could be present at a particular site.

3.1.1.1 *Early Development*

The earliest known explosive mixture discovered was what is now commonly referred to as black powder.A mixture of potassium nitrate, sulfur, and powdered charcoal or coal. [5] For over 1,200 years, black powder was the universal explosive and was used as a propellant for guns. For example, when ignited by fire or a spark from a flint, a loose charge of black powder above a gun's borehole or in a priming pan served as a priming composition. The train of black powder in the borehole served as a fuze composition. This combination resulted in the ignition of the propellant charge of black powder in the gun's barrel. When the projectile in the gun was a shrapnel type, the black powder in the delay fuze was ignited by the hot gases produced by the propellant charge, and the fuze then ignited the bursting charge of black powder.[6]

3.1.1.2 *Developments in the Nineteenth Century*

Black powder had its limitations; for example, it lacked the power to blast through rock for the purpose of making tunnels. The modern era of explosives began in 1838 with the first preparation of nitrocellulose. Like black powder, it was used both as a propellant and as an explosive. In the 1840s, nitroglycerine was first prepared and its explosive properties described. It was first used as an explosive by Alfred Nobel in 1864. The attempts by the Nobel family to market nitroglycerine were hampered by the danger of handling the liquid material and by the difficulty of safely detonating it by flame, the common method for detonating black powder. Alfred Nobel would solve these problems by mixing the liquid nitroglycerine with an absorbent, making it much safer to handle, and by developing the mercury fulminate detonator. The resulting material was called dynamite. Nobel continued with his research and in 1869 discovered that mixing nitroglycerine with nitrates and combustible material created a new class of explosives he named "straight dynamite." In 1875 Nobel discovered that a mixture of nitroglycerine and nitrocellulose formed a gel. This led to the development of blasting gelatin, gelatin dynamites, and the first double-base gun propellant, ballistite.[7]

In the latter half of the nineteenth century, events evolved rapidly with the first commercial production of nitroglycerine and a form of nitrocellulose as a gun propellant called smokeless powder. The usefulness of ammonium nitrate and additional uses of guncotton (another form of nitrocellulose) were discovered. Shortly thereafter, picric acid[8] began to be used as a bursting charge for projectiles. Additional diverse mixtures of various compounds with inert or stabilizing fillers were developed for use as propellants and as bursting charges.[9]

During the Spanish-American War, the United States continued its use of black powder as an artillery propellant. During this period, the U.S. Navy Powder Factory at Indian Head started

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[5]A mixture of potassium nitrate, sulfur, and powdered charcoal or coal.

[6]*Military Explosives*, TM 9-1300-214, Department of the Army, September 1984.

[7]A. Bailey and S.G. Murray. *Explosives, Propellants and Pyrotechnics.* Brassey's (UK) Ltd., 1989.

[8]Picric acid, 2,4,6-Trinitrophenol.

[9]*Military Explosives*, 1984.

manufacturing single-base powder. However, the U.S. Army was slow to adopt this material, not manufacturing single-base powder until about 1900. This pyrocellulose powder was manufactured by gelatinizing nitrocellulose by means of an ether-ethanol mixture, extruding the resulting colloid material, and removing the solvent by evaporation.[10] By 1909, diphenylamine had been introduced as a stabilizer.

Because of its corrosive action on metal casings to form shock-sensitive metal salts, picric acid was replaced by TNT[11] as a bursting charge for artillery projectiles. Ammonium picrate, also known as "Explosive D," was also standardized in the United States as the bursting charge for armor-piercing projectiles.

3.1.1.3 *World War I*

The advent of the First World War saw the introduction of lead azide as an initiator and the use of TNT substitutes, containing mixtures of TNT, ammonium nitrate, and in some cases aluminum, by all the warring nations. One TNT substitute developed was amatol, which consisted of a mixture of 80 percent ammonium nitrate and 20 percent TNT. (Modern amatols contain no more than 50 percent ammonium nitrate.) Tetryl was introduced as a booster explosive for projectile charges.[12]

3.1.1.4 *The Decades Between the Two World Wars*

The decades following World War I saw the development of RDX,[13] PETN,[14] lead styphnate, DEGDN,[15] and lead azide as military explosives. In the United States, the production of toluene from petroleum resulted in the increased production of TNT. This led to the production of more powerful and castable explosives such as pentolite.[16] Flashless propellants were developed in the United States, as well as diazodinitrophenol as an initiator.[17]

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[10]Ibid.

[11]TNT, 2,4,6-Trinitrotoluene.

[12]*Military Explosives*, 1984.

[13]RDX, Hexahydro-1,3,5-trinitro-1,3,5-triazine.

[14]Use of PETN, or pentaerythrite tetranitrate, was not used on a practical basis until after World War I. It is used extensively in mixtures with TNT for the loading of small-caliber projectiles and grenades. It has been used in detonating fuzes, boosters, and detonators.

[15]DEGDN, Diethylene glycol dinitrate.

[16]An equal mixture of TNT and PETN.

[17]*Military Explosives*, 1984.

3.1.1.5 *World War II*

The industrial development and manufacturing of synthetic toluene from petroleum just prior to World War II in the United States resulted in a nearly limitless supply of this chemical precursor of TNT. Because of its suitability for melt-loading, a process that heats the mixture to a near liquid state for introducing into the bomb casing, and for forming mixtures with other explosive compounds that could be melt-loaded, TNT was produced and used on an enormous scale during World War II. World War II also saw the development of rocket propellants based on a mixture of nitrocellulose and nitroglycerine or nitrocellulose and DEGDN. Tetrytol[18] and picratol,[19] special-purpose binary explosives used in demolition work and in semi-armor-piercing bombs, were also developed by the United States.[20]

RDX and HMX[21] came into use during World War II, but HMX was not produced in large quantities, so its use was limited.[22] Cyclotols, which are mixtures of TNT and RDX, were standardized early in World War II. Three formulations are currently used: 75 percent RDX and 25 percent TNT, 70 percent RDX and 30 percent TNT, and 65 percent RDX and 35 percent TNT.

A number of plastic explosives for demolition work were developed including the RDX-based C-3. The addition of powdered aluminum to explosives was found to increase their power. This led to the development of tritonal,[23] torpex,[24] and minol,[25] which have powerful blast effects. Also developed was the shaped charge, which permits the explosive force to be focused in a specific direction and led to its use for armor-piercing explosive rounds.[26]

3.1.1.6 *Modern Era*

Since 1945, military researchers have recognized that, based on both performance and cost, RDX, TNT, and HMX are not likely to be replaced as explosives of choice for military applications. Research has been directed into the optimization of explosive mixtures for special applications and for identifying and solving safety problems. Mixing RDX, HMX, or PETN into oily or polymer matrices has produced plastic or flexible explosives for demolition. Other polymers will produce tough, rigid, heat-resistant compositions for conventional missile warheads and for the conventional

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[18]A binary bursting charge explosive containing 70% tetryl and 30% TNT.

[19]A binary bursting charge explosive containing 52% ammonium picrate (Explosive D) and 48% TNT.

[20]*Military Explosives*, 1984.

[21]HMX, Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

[22]Bailey and Murray.

[23]A mixture of 80% TNT and 20% flaked aluminum.

[24]A mixture of 41% RDX, 41% TNT, and 18% aluminum.

[25]A mixture of TNT, ammonium nitrate, and aluminum.

[26]*Military Explosives*, 1984.

implosion devices used in nuclear weapons.[27]

3.1.2 Classification of Military Energetic Materials

Energetic materials used by the military consist of energetic chemical compounds or mixtures of chemical compounds. These are divided into three uses: explosives, propellants, and pyrotechnics. Explosives and propellants, if properly initiated, will evolve large volumes of gas over a short period of time. The key difference between explosives and propellants is the reaction rate. Explosives react rapidly, creating a high-pressure shock wave. Propellants react at a slower rate, creating a sustained lower pressure. Pyrotechnics produce heat but less gas than explosives or propellants.[28]

The characteristic effects of explosives result from a vast change in temperature and pressure developed when a solid, liquid, or gas is converted into a much greater volume of gas and heat. The rate of decomposition of particular explosives varies greatly and determines the classification of explosives into broadly defined groups.[29]

Military explosives are grouped into three classes:[30]

1. Inorganic compounds, including lead azide and ammonium nitrate
2. Organic compounds, including:
   a. Nitrate esters, such as nitroglycerine and nitrocellulose
   b. Nitro compounds, such as TNT and Explosive D
   c. Nitramines, such as RDX and HMX
   d. Nitroso compounds, such as tetrazene
   e. Metallic derivatives, such as mercury fulminate and lead styphnate
3. Mixtures of oxidizable materials, such as fuels, and oxidizing agents that are not explosive when separate. These are also known as binary explosives.

The unique properties of each class of explosives are utilized to make the "explosive train." One example of an explosive train is the initiation by a firing pin of a priming composition that detonates a charge of lead azide. The lead azide initiates the detonation of a booster charge of tetryl. The tetryl in turn detonates the surrounding bursting or main charge of TNT. The explosive train is illustrated in Figures 3-1 and 3-2.

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[27]Bailey and Murray.

[28]*Military Explosives*, 1984.

[29]*Military Explosives*, Department of the Army, TM 9-1910, April 1955.

[30]Ibid.

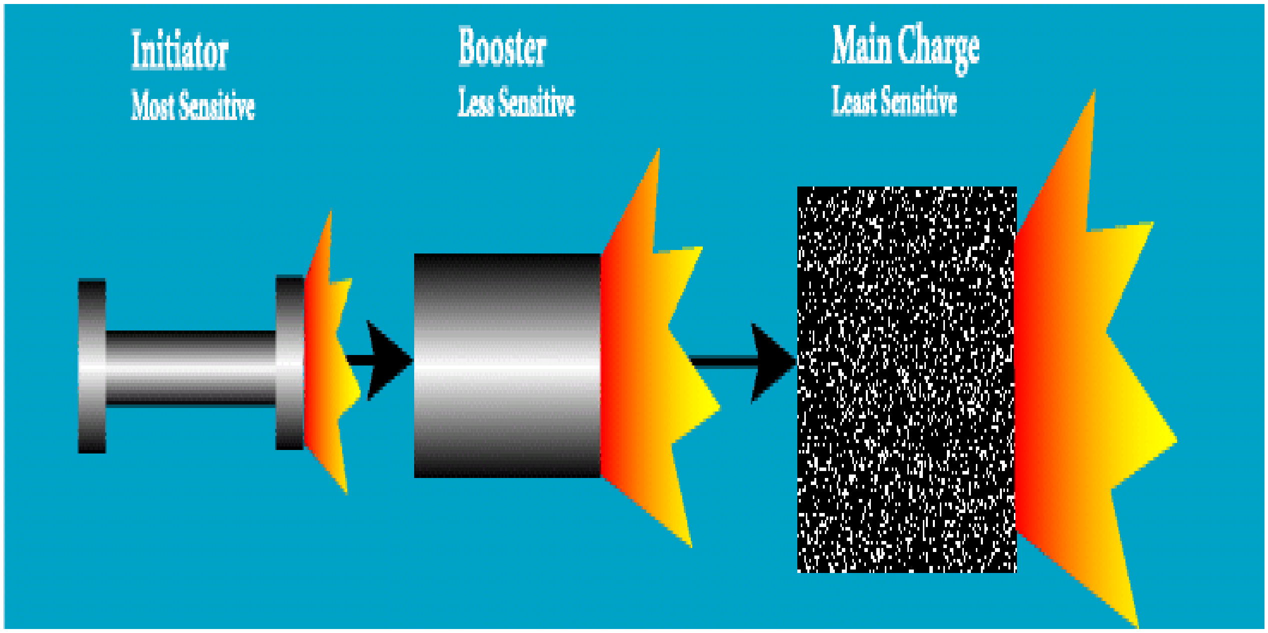

Figure 3-1. Schematic of an Explosive Train

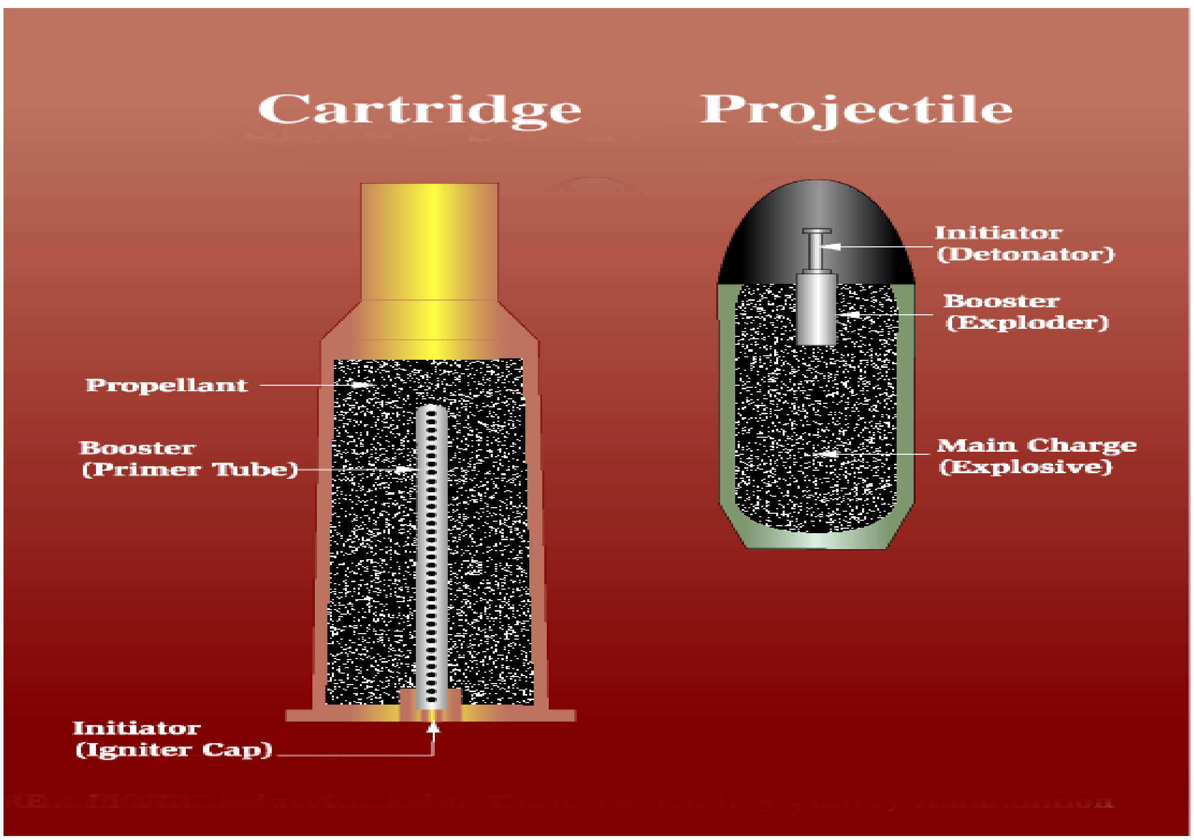

Figure 3-2. Explosive Trains in a Round of Artillery Ammunition

3.1.3 Classification of Explosives

An explosive is defined as a chemical material that, under the influence of thermal or mechanical shock, decomposes rapidly with the evolution of large amounts of heat and gas.[31] The categories **low explosive** and **high explosive** are based on the velocity of the explosion. High explosives are characterized by their extremely rapid rate of decomposition. When a high explosive is initiated by a blow or shock, it decomposes almost instantaneously, a process called detonation. A detonation is a reaction that proceeds through the reacted material toward the unreacted material at a supersonic velocity (greater than 3,300 feet per second). High explosives are further divisible by their susceptibility to initiation into primary and secondary high explosives. Primary or initiating high explosives are extremely sensitive and are used to set off secondary high explosives, which are much less sensitive but will explode violently when ignited. Low explosives, such as smokeless powder and black powder, on the other hand, combust at a slower rate when set off and produce large volumes of gas in a controllable manner. Examples of primary high explosives are lead azide and mercury fulminate. TNT, tetryl, RDX, and HMX are secondary high explosives. There are hundreds of different kinds of explosives and this handbook does not attempt to address all of them. Rather, it discusses the major classifications of explosives used in military munitions.

Chemicals Found in Pyrotechnics

Aluminum
Barium
Chromium
Hexachlorobenzene
Hexachloroethane
Iron
Magnesium
Manganese
Titanium
Tungsten
Zirconium
Boron
Carbon
Silicon
Sulfur
White Phosphorus
Zinc

Chlorates
Chromates
Dichromates
Halocarbons
Iodates
Nitrates
Oxides
Perchlorates

3.1.3.1 *Low Explosives, Pyrotechnics, Propellants, and Practice Ordnance*

Low explosives include such materials as smokeless powder and black powder. Low explosives undergo chemical reactions, such as decomposition or autocombustion, at rates from a few centimeters per minute to approximately 400 meters per second. Examples and uses of low explosives are provided below.

Pyrotechnics are used to send signals, to illuminate areas of interest, to simulate other weapons during training, and as ignition elements for certain weapons. Pyrotechnics, when ignited, undergo an energetic chemical reaction at a controlled rate intended to produce, on demand in various combinations, specific time delays or quantities of heat, noise, smoke, light, or infrared radiation. Pyrotechnics consist of a wide range of materials that in combination produce the desired effects. Some examples of these materials are found in the text box to the right.[32] Some pyrotechnic devices are used as military simulators and are designed to explode. For example, the M80 simulator, a paper cylinder containing the charge composition, is used to simulate rifle or artillery fire, hand grenades, booby

[31] R.N. Shreve. *Chemical Process Industries.* 3rd ed., McGraw-Hill, NY, NY, 1967.

[32] Ibid.

traps, or land mines.[33] Table 3-1 shows examples of pyrotechnic special effects.[34]

Table 3-1. Pyrotechnic Special Effects

Effect	Examples
Heat	Igniters, incendiaries, delays, metal producers, heaters
Light*	Illumination (both long and short periods), tracking, signaling, decoys
Smoke	Signaling, screening
Sound	Signaling, distraction

* Includes not only visible light but also nonvisible light, such as infrared.

Propellants are explosives that can be used to provide controlled propulsion for a projectile. Projectiles include bullets, mortar rounds, artillery rounds, rockets, and missiles. Because the projectile must be directed with respect to range and direction, the explosive process must be restrained. In order to allow a controlled reaction that falls short of an actual detonation, the physical properties of the propellant, such as the grain size and form, must be carefully controlled.

Historically, the first propellant used was black powder. However, the use of black powder (in the form of a dust or fine powder) as a propellant for guns did not allow accurate control of a gun's ballistic effects. The development of denser and larger grains of fixed geometric shapes permitted greater control of a gun's ballistic effects.[35]

Modern gun propellants consist of one or more explosives and additives (see text box). These gun propellants are often referred to as "smokeless powders" to distinguish these materials from black powder. They are largely smokeless on firing compared to black powder, which gives off more than 50 percent of its weight as solid products.[36]

All solid gun propellants contain nitrocellulose. As a nitrated natural polymer, nitrocellulose has the required mechanical strength and resilience to maintain its integrity during handling and firing. Nitrocellulose is partially soluble in some organic solvents. These solvents include acetone, ethanol, ether/ethanol, and nitroglycerine. When a mixture of nitrocellulose and solvent is worked, a gel forms. This gel retains the strength of the polymer structure of

Chemicals Found in Gun Propellants

Dinitrotoluenes (2,4 and 2,6)
Diphenylamine
Ethyl centralite
N-nitroso-diphenylamine
Nitrocellulose
Nitroglycerine
Nitroguanidine
Phthalates

[33] *Pyrotechnic Simulators*, TM 9-1370-207-10, Headquarters, Department of the Army, March 31, 1991.

[34] Bailey and Murray.

[35] *Military Explosives*, 1984.

[36] Bailey and Murray.

nitrocellulose. Other propellant ingredients include nitroglycerine and nitroguanidine.[37]

Modern gun propellants, classified according to composition, include the following:[38]

- Single-base. Nitrocellulose is the chief ingredient. In addition to a stabilizer, single-base propellants may contain inorganic nitrates, nitrocompounds, and nonexplosive materials as metallic salts, metals, carbohydrates, and dyes.
- Double-base. In addition to nitrocellulose, a double-base propellant contains a liquid organic nitrate such as nitroglycerine. Double-base propellants frequently contain additives, in addition to a stabilizer.
- Composite. Composite propellants do not contain nitrocellulose or organic nitrates. Generally, they are a physical mixture of an organic fuel and an inorganic oxidizing agent. An organic binding agent holds the mixture together in a heterogeneous physical structure.

Rocket propellants are explosives designed to burn smoothly without risk of detonation, thus providing smooth propulsion. Some classes of rocket propellants are similar in composition to the previously described gun propellants. However, due to the different requirements and operating conditions, there are differences in formulation. Gun propellants have a very short burn time with a high internal pressure. Rocket propellants can burn for a longer time and operate at a lower pressure than gun propellants.[39]

Rocket propellants can be liquid or solid. There are two types of liquid propellants: monopropellants, which have a single material, and bipropellants, which have both a fuel and an oxidizer. Currently, the most commonly used monopropellant is hydrazine. Bipropellants are used on very powerful launch systems such as space vehicle launchers. One or both of the components could be cryogenic material, such as liquid hydrogen and liquid oxygen. Noncryogenic systems include those used on the U.S. Army's tactical Lance missile. The Lance missile's fuel is an unsymmetrical demethylhydrazine. The oxidizer is an inhibited fuming nitric acid that contains nitric acid, dinitrogen tetroxide, and 0.5 percent hydrofluoric acid as a corrosion inhibitor.[40]

Unlike the liquid-fueled rocket motors, in which the propellant is introduced into a combustion chamber, the solid fuel motor contains all of its propellant in the combustion chamber. Solid fuel propellants for rocket motors consist of double-base, modified double-base, and composites. Double-base rocket propellants are similar to the double-base gun propellants discussed earlier. Thus, they consist of a colloidal mixture of nitrocellulose and nitroglycerine with a stabilizer. A typical composition for a double-base propellant consists of nitrocellulose (51.5%), nitroglycerine (43%), diethylphthalate (3%), potassium sulfate (1.25%), ethyl centralite (1%), carbon black (0.2%), and wax (0.05%).

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[37]Ibid.

[38]*Ammunition, General*. Department of the Army, TM 9-1300-200, October 3, 1969..

[39]Ibid.

[40]Ibid.

Modified double-base propellants provide a higher performance than double-base propellants. Two typical compositions for modified double-base propellants are (a) nitrocellulose (20%), nitroglycerine (30%), triacetin (6%), ammonium perchlorate (11%), aluminum (20%), HMX (11%), and a stabilizer (2%); or (b) nitrocellulose (22%), nitroglycerine (30%), triacetin (5%), ammonium perchlorate (20%), aluminum (21%), and a stabilizer (2%). Composite propellants consist of a polymer structure and an oxidizer. The oxidizer of choice is ammonium perchlorate.

Practice ordnance is ordnance used to simulate the weight and flight characteristics of an actual weapon. Practice ordnance usually carries a small spotting device to permit the accuracy of impact to be assessed.

3.1.3.2 *High Explosives*

High explosives includes compounds such as TNT, tetryl, RDX, HMX, and nitroglycerine. These compounds undergo reaction or detonation at rates of 1,000 to 8,500 meters per second. High explosives undergo much greater and more rapid reaction than low explosives (see 3.1.3.1). Some high explosives, such as nitrocellulose and nitroglycerine, are used in propellant mixtures. This conditioning often consists of mixing the explosive with other materials that permit the resulting mixture to be cut or shaped. This process allows for a greater amount of control over the reaction to achieve the desired effect as a propellant.

High explosives are further divisible into primary and secondary high explosives according to their susceptibility to initiation. Primary or initiating high explosives are extremely sensitive and are used to set off secondary high explosives, both booster and burster explosives, which are less sensitive but will detonate violently when ignited.

Primary Explosives

Lead azide
Lead styphnate
Mercury fulminate
Tetrazene
Diazodinitrophenol

Primary or initiating explosives are high explosives that are generally used in small quantities to detonate larger quantities of high explosives. Initiating explosives will not burn, but if ignited, they will detonate. Initiating agents are detonated by a spark, friction, or impact, and can initiate the detonation of less sensitive explosives. These agents include lead azide, lead styphnate, mercury fulminate, tetrazene, and diazodinitrophenol.

Booster or auxiliary explosives are used to increase the flame or shock of the initiating explosive to ensure a stable detonation in the main charge explosive. High explosives used as auxiliary explosives are less sensitive than those used in initiators, primers, and detonators, but are more sensitive than those used as filler charges or bursting explosives. Booster explosives, such as RDX, tetryl, and PETN, are initiated by the primary explosive and detonate at high rates.

Booster Explosives

RDX
Tetryl
PETN

Bursting explosives, main charge, or fillers are high explosive charges that are used as part of the explosive charge in mines, bombs, missiles, and projectiles. Bursting charge explosives, such as TNT, RDX compositions, HMX, and Explosive D, must be initiated by means of a booster explosive. Some common explosive compositions are discussed in the following text box.

Bursting Explosives

TNT
RDX compositions
HMX
Explosive D

Explosive Compositions

Explosive compounds are the active ingredients in many types of explosive compositions, such as Compositions A, B, and C. Composition A is a wax-coated, granular explosive consisting of RDX and plasticizing wax that is used as the bursting charge in Navy 2.75- and 5-inch rockets and land mines. Composition B consists of castable mixtures (substances that are able to be molded or shaped) of RDX and TNT and, in some instances, desensitizing agents that are added to the mixture to make it less likely to explode. Composition B is used as a burster in Army projectiles and in rockets and land mines. Composition C is a plastic demolition explosive consisting of RDX, other explosives, and plasticizers. It can be molded by hand for use in demolition work and packed by hand into shaped charge devices.

3.1.3.3 *Incendiaries*

Incendiaries are neither high nor low explosives but are any flammable materials used as fillers for the purpose of destroying a target by fire,[41] such as napalm, thermite, magnesium, and zirconium. In order to be effective, incendiary devices should be used against targets that are susceptible to destruction or damage by fire or heat. In other words, the target must contain a large percentage of combustible material.

3.2 Characteristics and Location of MEC

This section describes the sources of safety hazards posed by explosives and munitions.

3.2.1 <u>Hazards Associated with Common Types of Munitions</u>

The condition in which a munition is found is an important factor in assessing its likelihood of detonation. Munitions are designed for safe transport and handling prior to use. However, munitions that were abandoned or buried cannot be assumed to meet the criteria for safe shipment and handling without investigation. In addition, munitions that have been used but failed to function as designed (called unexploded ordnance, duds, or dud-fired) may be armed or partially armed. As a category of munitions, UXO is the most hazardous and is normally not safe to handle or transport. Although it may be easy to identify the status (fuzed or not fuzed) of some munitions (e.g., abandoned), this is generally not the case with buried munitions or UXO. Many munitions use multiple fuzing options; one fuze may be armed and others may not be armed. Therefore, common sense dictates that all munitions initially be considered armed until the fuze can be properly investigated and the fuze condition determined.

[41] Naval Explosive Ordnance Disposal Technology Division, Countermeasures Department. *Unexploded Ordnance: An Overview*, 1996.

Ammunition Classification

Ammunition is typically classified in accordance with the following five factors:

- **Type:** see following text box
- **Use:** service, practice, inert
- **Filler:** explosive, chemical, leaflet, or inert
- **Storage:** amount of explosives (quantity-distance classes)
- **Compatibility:** for storage purposes

Munitions that detonate only partially are said to have undergone a “low order” detonation, which may result in exposed explosives scattered in the immediate vicinity. In addition to the detonation hazard of UXO varying with the condition in which it is found, the explosive hazard also varies with the type of munition, as briefly described in the following text box.

Ammunition Types

Ammunition is classified according to the following types:

(1) **Small arms ammunition.** Small arms ammunition (less that 20mm) consists of cartridges used in rifles, carbines, revolvers, pistols, submachine guns, and machine guns and shells used in shotguns. They do not contain explosives; therefore, they present minimal explosive risks (propellant or tracer only) but do contain lead projectiles and may cause lead contamination.
(2) **Grenades.** Grenades are explosive- or chemical-filled projectiles of a size and shape convenient for throwing by hand or projecting from a rifle. These munitions are designed to land on the ground surface and therefore are more accessible. Fragmentation grenades, most commonly used, break into small, lethal, high-velocity fragments and pose the most hazards.
(3) **Artillery ammunition.** Artillery ammunition consists of cartridges or shells that are filled with high-explosive, chemical, or other active agents; and projectiles that are used in guns, howitzers, mortars, and recoilless rifles. They are typically deployed from the ground, but may also be placed on aircraft and generally used in the indirect fire mode. Fuze types include proximity, impact, or time-delay, depending on the mission and the intended target. They may also contain submunitions that are sensitive to any movement.
(4) **Bombs.** Bombs are containers filled with explosive, chemical, or other active agents, designed for release from aircraft. Bombs penetrate the ground to depths than other munitions due to the size and weight of the munition. They may also contain submunitions that are very sensitive to movement.
(5) **Pyrotechnics.** Pyrotechnics consist of containers filled with low-explosive composition, designed for release from aircraft or for projection from the ground for illumination or signals (colored smokes).
(6) **Rockets.** Rockets are propellant-type motors fitted with rocket heads containing high-explosive or chemical agents. The residual propellant may burn violently if subjected to sharp impact, heat, flame, or sparks.
(7) **Jet Assisted Take-Off System (JATOS).** JATOS consists of propellant-type motors used to furnish auxiliary thrust in the launching of aircraft, rockets, guided missiles, target drones, and mine-clearing detonating cables.
(8) **Land mines.** Land mines are metal or plastic containers that contain high-explosive or chemical agents designed for laying in (normally within the first 12 inches or the topsoil) or on the ground for initiation by, and effect against, enemy vehicles or personnel.
(9) **Guided missiles.** Guided missiles consist of propellant-type motors fitted with warheads containing high-explosive or other active agent and equipped with electronic guidance devices.

Ammunition Types (continued)

(10) **Demolition materials.** Demolition materials consist of explosives and explosive devices designed for use in demolition and in connection with blasting for military construction.
(11) **Cartridge-actuated devices (CAD).** Cartridge-actuated devices are devices designed to facilitate an emergency escape from high-speed aircraft.

Adapted from:

JCS PUB 1-02. DoD Dictionary of Military and Associated Terms. March 23, 1994.
AR 310-25. Dictionary of United States Army Terms. May 21, 1996.
TM 9-1300-200. Ammunition, General.
FM 21-16. Unexploded Ordnance (UXO) Procedures. August 30, 1994.

3.2.2 Areas Where MEC is Found

Areas that are most likely to contain MEC include munitions manufacturing plants; load, assemble, and pack operations; military supply depots; ammunition depots; proving grounds; open detonation (OD) and open burning (OB) grounds; range impact areas; range buffer zones; explosive ordnance disposal sites; live-fire areas; training ranges; and ordnance test and evaluation (T&E) facilities and ranges. The primary ordnance-related activity will also assist planners in determining the potential MEC hazards at the site; for example, an impact area will have predominantly unexploded ordnance (fuzed and armed), whereas munitions manufacturing plants should have only ordnance items (fuzed or unfuzed but unarmed). At all of these sites, a variety of munition types could have been used, potentially resulting in a wide array of MEC items at the site. The types and quantities of munitions employed may have changed over time as a result of changes in the military mission and advances in munitions technologies, thus increasing the variety of MEC items that may be present at any individual site. Changes in training needs also contribute to the presence of different MEC types found at former military facilities.

The types of munitions constituents potentially present on ranges varies, de-pending on the range type and its use. For example, a rifle range would be expected to be contaminated with lead rounds and metal casings. For ranges used for bombing, the most commonly found munitions constituents would consist of explosive compounds such as TNT and RDX. This has been confirmed by environmental samples collected at numerous facilities. For example, TNT or RDX is usually present in explosives-contaminated soils.

Military Ranges

The typical setup of **bombing and gunnery ranges (including live-fire and training ranges)** consists of one or more "targets" or "impact areas," where fired munitions are supposed to land. Surrounding the impact area is a buffer zone that separates the impact area from the firing/release zone (the area from which the military munitions are fired, dropped, or placed). Within the live fire area, the impact area usually contains the greatest concentration of UXO. Buried munitions may be found in other areas, including the firing area itself.

A **training range**, **troop maneuver area, or troop training area** is used for conducting military exercises in a simulated conflict area or war zone. A training range can also be used for other nonwar simulations such as UXO training. Training aids and military munitions simulators such as training ammunition, artillery simulators, smoke grenades, pyrotechnics, mine simulators, and riot control agents are used on the training range. While these training aids are safer than live munitions, they may still present explosive hazards.

Studies of sampling and analysis at a number of explosives-contaminated sites reported "hits" of TNT or RDX in 72 percent of the contaminated soil samples collected[42] and up to 94 percent of contaminated water samples collected.[43]

Early (World War I era) munitions tended to be TNT- or Explosive D (ammonium picrate)-based. To a lesser extent, tetryl and ammonium nitrate were used as well. TNT is still used, but mixtures of RDX, HMX, ammonium picrate, PETN, tetryl, and aluminum came into use during World War II. Incendiary charges also were used in World War II.

3.2.3 Release Mechanisms for MEC

The primary mechanisms for the occurrence and/or release of MEC at MRS are based on the type of MEC activity or are the result of improper functioning (e.g., detonation) of the MEC. For example, when a bomb or artillery projectile is dropped or fired, it will do one of three things:

- It will detonate completely. This is also called a "high order" detonation. Complete detonation causes a "release" of both munitions debris (e.g., fragments) and small quantities of munitions constituents (e.g., energetic compounds such as TNT and RDX, lead and other heavy metals) into the environment. Release also may occur during open detonation of munitions during range-clearing operations.
- It will undergo an incomplete detonation, also called a "low order" detonation. This causes a release of not only munitions debris and larger amounts of munitions constituents into the environment, but also larger pieces of the actual munition itself.
- It will fail to function, or "dud fire," which results in UXO. The UXO may be completely intact, in which case releases of munitions constituents are less likely; or the UXO may be damaged or in an environment that subjects it to corrosion, thus releasing munitions constituents over time.

> **Sampling of Detonation Residues**
>
> Analysis of soil samples for explosive residues in areas of high-order and low-order detonation reveals that significantly higher quantities of residue are present at low-order detonation sites. The levels of munitions constituents released from high-order detonations are so low as to be measured in micrograms.
>
> *Source: Sampling for Explosives Residues at Fort Greely, Alaska,* Reconnaissance Site Visit July 2000, ERDC/CRREL TR-01-015, November 2001.

In addition, MEC could be lost, abandoned, or buried, resulting in bulk munitions that could be fuzed or unfuzed. If such an MEC item is in an environment that is corrosive or otherwise damaging to the MEC item, or if the MEC item has been damaged, munitions constituents could leach out of the ordnance item.

The fate and transport of some munitions constituents in the environment have not yet

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[42] A.B. Crockett, H.D. Craig, T.F. Jenkins, and W.E. Sisk. *Field Sampling and Selecting On-Site Analytical Methods for Explosives in Soils*, U.S. Environmental Protection Agency, EPA/540/R-97/501, November 1996.

[43] A.B. Crockett, H.D. Craig, and T.F. Jenkins. *Field Sampling and Selecting On-Site Analytical Methods for Explosives in Water*, U.S. Environmental Protection Agency, EPA/600/S-99/002, May 19, 1999.

received the level of focus of some more commonly found chemicals associated with other military operations (such as petroleum hydrocarbons in groundwater from jet fuels). For example, TNT adsorbs to soil particles and is therefore not expected to migrate rapidly through soil to groundwater. However, the behavior in the environment of TNT's degradation products is not well understood at this time, nor is the degree to which TNT in soil might be a continuing low-level source of groundwater contamination.

DoD is currently investing additional resources to better understand the potential for corrosion of intact UXO in different environments and to better quantify the fate and transport of other munitions constituents.

3.2.4 Chemical Reactivity of Explosives

Standard military explosives are reactive to varying degrees, depending on the material, conditions of storage, or environmental exposure. Precautions must be taken to prevent their reacting with other materials. For example, lead azide will react with copper in the presence of water and carbon dioxide to form copper azide, which is an even more sensitive explosive.[44] Ammonium nitrate will react with iron or aluminum in the presence of water to form ammonia and metal oxide. TNT will react with alkalis to form dangerously sensitive compounds.[45] Picric acid easily forms metallic compounds, many of which are very shock sensitive.

Because of these reactions, and others not listed, military munitions are designed to be free of moisture and any other impurities. Therefore, munitions that have not been properly stored may be more unstable and unpredictable in their behavior, and more dangerous to deal with than normal munitions. This is also true for munitions that are no longer intact, have been exposed to weathering processes, or have been improperly disposed of. These conditions may exist on ranges.

3.3 Sources and Nature of the Potential Hazards Posed by Conventional Munitions

This section of the handbook addresses two factors that affect the potential hazards posed by conventional munitions: (1) the sensitivity of the munition and its components (primarily the fuze and fuze type) to detonation, and (2) the environmental and human factors that affect the deterioration of the MEC or the depth at which MEC is found.

The potential for the hazards posed by conventional munitions is a result of the following:

- Type of munition
- Type and amount of explosive(s) contained in the munition
- Type of fuze
- The potential for deterioration of the intact UXO and the release of munitions constituents
- The likelihood that the munition will be in a location where disturbance is possible or probable

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[44] *Military Explosives*, 1955.

[45] Ibid.

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However, a full understanding of the potential hazards posed by conventional munitions is not possible prior to initiating an investigation unless the munition items have been identified in advance, the state of the munitions is known, and the human and environmental factors (e.g., frost heave) are well understood.

3.3.1 Probability of Detonation as a Function of Fuze Characteristics

Most military munitions contain a fuze that is designed to either ignite or cause the detonation of the payload containing the munition. Although there are many types of fuzes, all are in one of three broad categories — mechanical, electronic, or a combination of both. These fuze types describe the method by which a fuze is armed and fired. Modern fuzes are generally not armed until the munition has been launched. For safety purposes, DoD policy is that all munitions and MEC found on ranges should be assumed to be armed and prepared to detonate and should be approached with extreme caution (see Chapter 6, "Explosives Safety").

The type of fuze and its condition (armed or unarmed) directly determine its sensitivity. **It should always be assumed that a fuzed piece of ordnance is armed**. Many fuzes have backup features in addition to their normal method of firing. For example, a proximity fuze may also have an impact or self-destruct feature. Also, certain types of fuzes are more sensitive than others and may be more likely to explode upon disturbance. Some of the most common fuzes are described below.

- **Impact fuzes** are designed to function upon direct impact with the target. Some impact fuzes may have a delay element. This delay lasts fractions of a second and is designed to allow the projectile to penetrate the target before functioning. Examples of specific impact fuzes include impact inertia, concrete piercing, base detonating, all-way acting, and multi-option. (An example of an all-way-acting fuze is shown in Figure 3-3.) In order for a proximity or impact fuze to arm, the projectile must be accelerating at a predetermined minimum rate. If the acceleration is too slow or extends over too short a period of time, the arming mechanism returns to its safety position; however, munitions with armed proximity fuzes that have not exploded may be ready to detonate on the slightest disturbance, especially if the movement generates a static electric charge.
- **Mechanical time fuzes** use internal movement to function at a predetermined time after firing. Some of these fuzes may have a backup impact fuze. Moving UXO with this type of fuze may also cause a detonation. An example of a mechanical time super-quick fuze is shown in Figure 3-4.
- **Powder train time fuzes** use a black powder train to function at a predetermined time after firing.
- **Proximity fuzes** are designed to function only when they are at a predetermined distance from a target.[46] They are used in air-to-ground and ground-to-ground operations to create airbursts above the target, and they do not penetrate and detonate within the target, as do impact fuzes. A proximity fuze by design uses a sophisticated sensor to signal the proximity to the target as the initiation source for the detonation. In a dud-fired condition, the main concern is the outside influence exerted by an electromagnetic (EM) source. EM sources include two-way radios and cell phones; therefore, the use of such items must not

[46]Major N. Lantzer et al. *Risk Assessment: Unexploded Ordnance*, Prepared for NAVEODTECHDIV, 1995.

be permitted in these types of environments. EM sources also include certain geophysical instruments, such as the EM-61 (see discussion of EM-61 and related geophysical sensors in Chapter 4). Proximity fuzes sometimes are backed up with an impact fuze designed to function on target impact if the proximity mode fails to function.

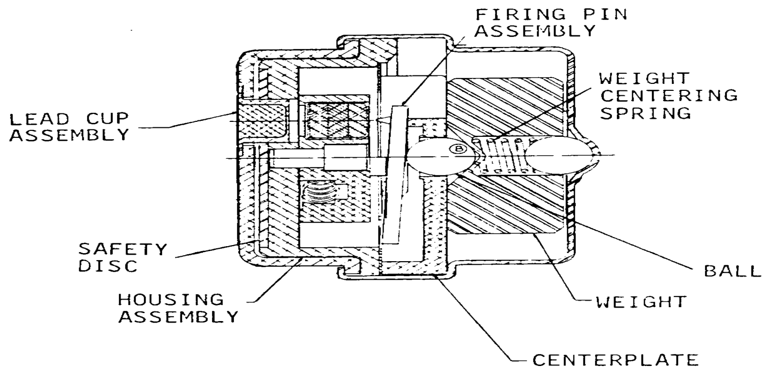

Figure 3-3. Mechanical All-Way-Acting Fuze

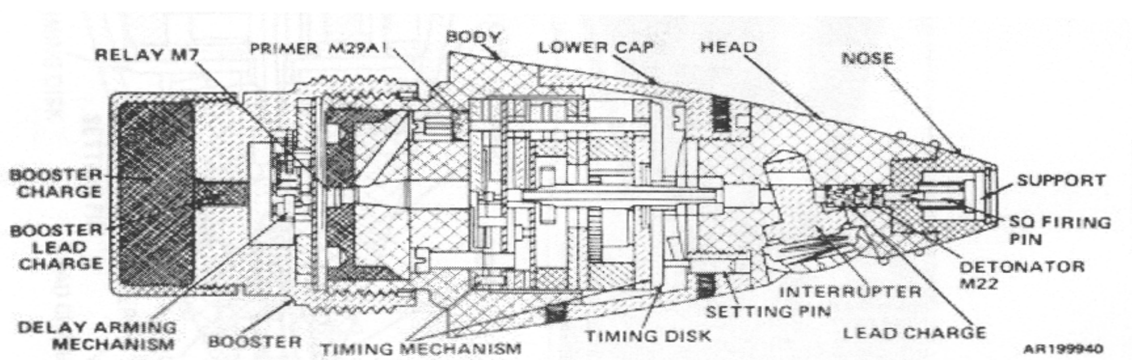

Figure 3-4. Mechanical Time Super-Quick Fuze

Arming of Fuzes

The material that follows is designed to provide an example of how fuzes are armed. This example relates to one specific type of weapons system.

Rocket fuzes are classified according to location in the warhead as point detonating (PD), base detonating (BD), or point initiating, base detonating (PIBD). They are further classified according to method of functioning as time, proximity, or impact.

a. Time fuzes function a preselected number of seconds after the round is fired. Impact fuzes function upon impact with super-quick, delay, or nondelay action.

(1) In the case of super-quick action, the warhead functions almost instantaneously on impact, initiated by a firing pin driven into a detonator.

(2) In delay action fuzes, the warhead functions a fixed time after impact to permit penetration of the target before the warhead explodes. The amount of delay, usually between 0.025 and 0.15 second, depends on the delay element incorporated in the fuze. Arming may be accomplished by mechanical means utilizing gear trains, air stream (air arming), spring action, centrifugal force or inertia, gas pressure (pressure arming), or a combination thereof.

(3) Nondelay action, somewhat slower than super-quick, occurs in delay-action fuzes when the black powder normally contained in the delay element has been removed.

b. The proximity fuze detonates the warhead at a distance from the target to produce optimum blast effect. It is essentially a radio transmitting and receiving unit and requires no prior setting or adjustment. Upon firing, after the minimum arming time, the fuze arms and continually emits radio waves. As the rocket approaches the target, the waves are reflected back to the fuze. The reflected waves are then received by the fuze with a predetermined intensity, as on approaching close to the target, this operates an electronic switch in the fuze. This permits electric current to flow through an electric squib, initiating the explosive train and detonating the rocket.

c. The PIBD fuze detonates the rocket on impact with the target. The fuze consists of a nose assembly and a base assembly connected by a wire passing through a conduit in the rocket head. Pressure of impact on a piezoelectric crystal in the nose assembly generates a surge of electricity. This is transmitted to a low-energy detonator in the base assembly, detonating it. Some PIBD fuzes have a graze-sensitive element which will actuate the fuze if impact does not initiate the piezoelectric crystal.

TM 9-1300-200, Section VI. FUZES

3.3.2 Types of Explosive Hazards

Both planned and accidental detonations can cause serious injury or even death and can seriously damage structures in the vicinity of the explosion. Explosive hazards from munitions vary with the munition components, explosive quantities, and distance from potential receptors. The DDESB has established minimum safety standards for the quantity of explosives and their minimum separation distance from surrounding populations, structures, and public areas for the protection of personnel and facilities during intentional and accidental explosions.[47] (DDESB is currently in the process of revising the safety standards.) These DDESB standards, called Quantity-Distance

[47] *DoD Ammunition and Explosives Safety Standards*, DoD 6055.9-STD, Chapters 2, 5, and 8, July 1999.

Standards, are based on research and accident data on the size of areas affected by different types of explosions and their potential human health and environmental impacts (see Chapter 6 for a discussion of quantity-distance standards). State and local authorities may have additional or more stringent quantity-distance requirements.

Understanding the explosive hazards specific to the munitions at your site will help you plan the appropriate safety precautions and notification of authorities. The primary effects of explosive outputs include blast pressure, fragmentation, and thermal hazards. Shock hazards are also a concern but are more of an issue with respect to storage of munitions in underground bunkers at active ranges. Each of these hazards is described below. Many MEC hazards in the field may result in more than one type of explosive output.

Blast pressure (overpressure) is the almost instantaneous pressure increase resulting from a violent release of energy from a detonation in a gaseous medium (e.g., air). The health hazards of blast pressure depend on the amount of explosive material, the duration of the explosion, and the distance from the explosion, and can include serious damage to the thorax or the abdominal region, eardrum rupture, and death.

Fragmentation hazards result from the shattering of an explosive container or from the secondary fragmentation of items in close proximity to an explosion. Fragmentation can cause a variety of physical problems ranging from skin abrasions to fatal injuries.

Thermal hazards are those resulting from heat and flame caused by a deflagration or detonation. Direct contact with flame, as well as intense heat, can cause serious injury or death.

Shock hazards result from underground detonations and are less likely to occur at MRSs than at active ranges or industrial facilities where munitions are found. When a munitions item is buried in the earth (e.g., stored underground), if detonation occurs, it will cause a violent expansion of gases, heat, and shock. A blast wave will be transmitted through the earth or water in the form of a shock wave. This shock wave is comparable to a short, powerful earthquake. The wave will pass through earth or water just as it does through air, and when it strikes an object such as a foundation, the shock wave will impart its energy to the structure.

Practice rounds of ordnance may have their own explosive hazards. They often contain spotting charges, which are low explosives or pyrotechnic fillers designed to produce a flash and smoke when detonated, providing observers or spotters a visual reference of ordnance impact. Practice UXO found on the ranges must be checked for the presence of unexpended spotting charges that could cause severe burns.

3.3.3 Factors Affecting Potential for Exposure to MEC

Because exposure to MEC is a key element of explosive risk, any action that makes MEC more accessible adds to its potential explosive risks. The combined factors of naturally occurring and human activities, such as the following, increase the risk of explosion from MEC:

- Flooding and erosion
- Frost heaving

- Agricultural activities
- Construction
- Recreational use (may provide open access)

Heavy flooding can loosen and displace soils, causing MEC located on or beneath the ground surface to be moved or exposed. In flooded soils, MEC could potentially be moved to the surface or to another location beneath the ground surface. Similarly, soil erosion due to high winds, flooding, or inadequate soil conservation could displace soils and expose MEC, or it could cause MEC to migrate to another location beneath the surface or up to the ground surface. Frost heaving is the movement of soils during the freeze-thaw cycle. Water expands as it freezes, creating uplift pressure. In nongranular soils, MEC buried above the frost line may migrate with frost heaving. The effects of these and other geophysical processes on the movement of MEC in the environment, while known to occur, are being studied more extensively by DoD.

Human activities can also increase the potential for exposure to MEC. Depending on the depth of munitions and explosives, agricultural activities such as plowing and tilling may loosen and disturb the soil enough to cause MEC to migrate to the surface, or such activities may increase the chances of soil erosion and MEC displacement during flooding. Further, development of land containing MEC may cause the MEC to be exposed and possibly to detonate during construction activities. Excavating soils during construction can expose MEC, and the vibration of some construction activities may create conditions in which MEC may detonate. All of these human and naturally occurring factors can increase the likelihood of MEC exposure, and therefore the explosive risks, of MEC.

3.3.4 Depth of MEC

The depth at which MEC is located is a primary determinant of both potential human exposure and the cost of investigation and response. In addition, the DoD Ammunition and Safety Standards require that an estimate of expected depth of MEC be included in the site-specific analysis for determining response depth.[48] A wide variety of factors may affect the depth at which MEC is found, including penetration depth — a function of munition size, shape, propellant charge used, soil characteristics, and other factors — as well as movement of MEC due to frost heave or other factors, as discussed in Section 3.3.3.

There are several methods for estimating the ground penetration depths of ordnance. These methods vary in the level of detail required for data input (e.g., ordnance weight, geometry, angle of entry), the time and level of effort needed to conduct analysis, and the assumptions used to obtain results. Some of the specific soil characteristics that affect ordnance penetration depth include soil type (e.g., sand, loam, clay), whether vegetation is present, and soil moisture. Other factors affecting penetration depth include munition geometry, striking velocity and angle, relative location of firing point and striking point, topography between firing point and striking point, and angle of entry. Table 3-2 provides examples of the potential effects that different soil characteristics can have on penetration depth. These depths do not reflect the variety of other factors (e.g., different striking velocities and angles) that affect the actual depth at which the munition may be found. The depths

[48] *DoD Ammunition and Explosives Safety Standards*, DoD 6055.9-STD, Chapter 12, July 1999.

provided in Table 3-2 are taken from a controlled study to determine munition penetration into earth. They are presented here to give the reader an understanding of the wide variability in the depths at which individual munitions may be found, based on soil characteristics alone.

While Table 3-2 provides a few examples of penetration depths, it does not illustrate the dramatic differences possible within ordnance categories. For example, rockets can penetrate sand to depths of between 0.4 and 8.1 feet, and clay to depths of between 0.8 and 16.3 feet, depending on the type of rocket and a host of site-specific conditions.[49]

Table 3-2. Examples of Depths of Ordnance Penetration into Soil

Type of Munition	Ordnance Item	Depth of Penetration (ft)			
		Limestone	Sand	Soil Containing Vegetation	Clay
Projectile	155 mm M107	2	14	18.4	28
Projectile	75 mm M48	0.7	4.9	6.5	9.9
Projectile	37 mm M63	0.6	3.9	5.2	7.9
Grenade	40 mm M822	0.5	3.2	4.2	6.4
Projectile	105 mm M1	1.1	7.7	10.1	15.4
Rocket	2.36" Rocket	0.1	0.4	0.5	0.8

Sources: U.S. Army Corps of Engineers, *Ordnance and Explosives Response: Engineering and Design*, EM 1110-1-4009, June 23, 2000; Ordata II, NAVEODTECHDIV, Version 1.0; and Crull Michelle et al., *Estimating Ordnance Penetration Into Earth*, paper presented at UXO Forum 1999, May 1999.

A unique challenge in any investigation of MEC is the presence of underground munition burial pits, which often contain a mixture of used, unused, or fired munitions as well as other wastes. Munition burial pits, particularly those containing a mixture of deteriorated munitions, can pose explosive and environmental risks. The possibility of detonation is due to the potentially decreased stability and increased likelihood of explosion of commingled and/or degraded munitions constituents.

Buried munitions may detonate from friction, impact, pressure, heat, or flames of a nearby munitions item that has been disturbed. Adding to the challenge, some burial pits are quite old and may not be secured with technologically advanced liners or other types of controls. Further, because some burial pits are very old, records of their contents or location may be incomplete or absent altogether.

3.3.5 Environmental Factors Affecting Decomposition of MEC

Deteriorated MEC can present serious explosive hazards. As MEC ages, the explosive compound/mixtures in MEC items can remain viable and could increase in sensitivity.[50]

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[49] U.S. Army Corps of Engineers. *Interim Guidance for Conventional Ordnance and Explosives Removal Actions*, October 1998.

[50] U.S. Army Corps of Engineers. *Ordnance and Explosives (MEC) Response Workshop*. Control #399, USACE Professional Development Support Center, FY01.

The probability of corrosion of an intact MEC item is highly site specific. MEC can resist corrosion under certain conditions. There are sites dating back to World War I in Europe that contain subsurface MEC that remains intact and does not appear to be releasing any munitions constituents. However, there are certain environments, such as MEC exposed to seawater, that can cause the MEC[51] to degrade. In addition, as MEC casings degrade under certain environmental conditions, or if the casings were damaged upon impact, their fillers, propellants, and other constituents may leach into the surrounding soils and groundwater.

In general, the likelihood of deterioration depends on the integrity and thickness of the MEC casing, as well as the environmental conditions in which the MEC item is located and the degree of damage to the item after being initially fired. Most munitions are designed for safe transport and handling prior to use. However, if they fail to explode upon impact, undergo a low-order detonation, or are otherwise damaged, it is possible that the fillers, propellants, and other munitions constituents may leach into surrounding soils and groundwater, potentially polluting the soil and groundwater and/or creating a mixture of explosives and their breakdown products. Anecdotal evidence at a number of facilities suggests adverse impacts to soil and groundwater from ordnance-related activities.

The soil characteristics that may affect the likelihood and rate of MEC casing corrosion include but are not limited to the following:

- Soil moisture
- Soil type
- Soil pH
- Buffering capacity
- Resistivity
- Electrochemical potential oxidation-reduction (“redox”)
- Oxygen
- Microbial corrosion

Study of Corrosion Rates in Soils

The potential extent of corrosion of the metal casing of intact UXO remains an area of scientific uncertainty. Conditions that facilitate or retard corrosion are clearly site-specific. The Army Environmental Center is undertaking a study of metallic corrosion rates as a function of soil and climatic conditions to create a predictive database of such information.

Moisture, including precipitation, high soil moisture, and the presence of groundwater, contribute to the corrosion of UXO and to the deterioration of explosive compounds. Soils with a low water content (i.e., below 20 percent) are slightly corrosive on UXO casings, and soils with periodic groundwater inundation are moderately corrosive.

The texture and structure of soil affect its corrosivity. Cohesive soils, those with a high percentage of clay and silt material, are much less corrosive than sandy soils. Soils with high organic carbon content, such as swamps, peat, fens, or marshes, as well as soils that are severely polluted with fuel ash, slag coal, or wastewater, tend to be highly corrosive.

The pH level also affects soil corrosivity. Normal soils with pH levels between 5 and 8 do not contribute to corrosivity. In fact, soils with pH above 5 may form a calcium carbonate coating on

[51] MEC specifically designed for use in a marine environment, such as sea mines and torpedoes, would not be included in this scenario.

buried metals, protecting them from extensive corrosion. However, highly acidic soils, such as those with a pH below 4, tend to be highly corrosive.

Buffering capacity, the measure of the soil's ability to withstand extreme changes in pH levels, also affects its corrosion potential. Soils with a high buffering capacity can maintain pH levels even under changing conditions, thereby potentially inhibiting corrosive conditions. However, soils with a low buffering capacity that are subject to acid rain or industrial pollutants may drop in pH levels and promote corrosivity.

Another factor affecting the corrosive potential of soils is resistivity, or electrical conductivity, which is dependent on moisture content and is produced by the action of soil moisture on minerals. At high resistivity levels (greater than 20,000 ohm/cm) there is no significant impact on corrosion; however, corrosion can be extreme at very low resistivity levels (below 1,000 ohm/cm). High electrochemical potential can also contribute significantly to UXO casing corrosion. The electrochemical or "redox" potential is the ability of the soil to reduce or oxidize UXO casings (the oxidation-reduction potential). Aerated soils have the necessary oxygen to oxidize metals.

3.3.6 Explosives-Contaminated Soils

A variety of situations can create conditions of contaminated and potentially reactive and/or ignitable soils, including the potential for low-order detonations, deterioration of the UXO container and leaching of munitions constituents into the environment, residual propellants ending up in soils, and OB/OD, which may disperse chunks of bulk explosives and munitions constituents. Soils with a 12 percent or greater concentration of secondary explosives, such as TNT and RDX, are capable of propagating (transmitting) a detonation if initiated by flame. Soils containing more than 15 percent secondary explosives by weight are susceptible to initiation by shock. In addition, chunks of bulk explosives in soils will detonate or burn if initiated, but a detonation will not move through the soil without a minimum explosive concentration of 12 percent. To be safe, the U.S. Army Environmental Center considers all soils containing 10 percent or more of secondary explosives or mixtures of secondary explosives to be reactive or ignitable soil.[52] Therefore, soils suspected of being contaminated with primary explosives may be very dangerous, and no work should be attempted until soil analysis has determined the extent of contamination and a detailed work procedure has been approved.[53] The soil analysis can be qualitative, that is, based on visual observations, as soils contaminated in the percent range are easy to spot; or analysis can be quantitative, using a field analysis kit such as those described in Chapter 8. Under no circumstances should soil visibly contaminated with munitions constituents be sampled or shipped offsite to a laboratory as it may create a hazard for the sampling crew members and the laboratory.

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[52]Federal Remediation Technologies Roundtable and USACE. *ETL Ordnance and Explosives Response*, 1110-1-8153, May 14, 1999.

[53]U.S. Army Corps of Engineers. *Ordnance and Explosives Response: Engineering Design*, EP 1110-1-18, April 2000.

3.4 Toxicity and Human Health and Ecological Impacts of Explosives and Other Munitions Constituents

The human health and environmental risks of other munitions constituents from MEC are caused by explosives or other chemical components, including lead and mercury, in munitions and from the compounds used in or produced during munitions operations. When exposed to some of these munitions constituents, humans may potentially face long-term health problems, including cancer. Similarly, exposure of ecosystems may cause disturbance of habitat and development of health and behavioral problems in the exposed receptors. The adverse effects of munitions constituents are dependent on the concentration of the chemicals and the pathways by which receptors become exposed. Understanding the human health and environmental risks of munitions constituents and byproducts requires information about the inherent toxicity of these chemicals and the manner in which they may migrate through soil and water toward potential human and environmental receptors. This section provides an overview of some commonly found explosive compounds and their potential health and ecological impacts.

Explosive compounds that have been used in or are byproducts of munitions use, production, operations (load, assemble, and pack), and demilitarization or destruction operations include, but are not limited to, the list of substances in Table 3-3. Other toxic materials, such as lead, are found in the projectiles of small arms. These explosive and otherwise potentially toxic compounds can be found in soils, groundwater, surface waters, and air and have potentially serious human health and ecological impacts. The nature of these impacts, and whether they pose an unacceptable risk to human health and the environment, depend upon the dose, duration, and pathway of exposure, as well as the sensitivity of the exposed populations.

3.4.1 <u>Human Health Effects</u>

Table 3-3 lists common munitions constituents and their uses. Many compounds have multiple uses, such as white phosphorus, which is both a bursting smoke and incendiary and can function as a pyrotechnic. The list of classifications in Table 3-3 is not intended to be all-inclusive but to provide a summary of some of the more common uses for various explosive materials.

Perchlorate

Perchlorate is a component of solid rocket fuel that has recently been detected in drinking water in States across the United States. Perchlorate interacts with the thyroid gland in mammals, with potential impacts on growth and development. Research continues to determine the maximum safe level for human drinking water. While perchlorate is not currently listed on EPA's IRIS database, several States, including California, have developed interim risk levels.

Table 3-3. Primary Uses of Explosive Materials

Compound	Propellant	Primary or Initiator	Booster	Burster Charge	Pyrotechnics	Incendiary
TNT				C		
RDX			C	C		
HMX			C	C		

Table 3-3. Primary Uses of Explosive Materials (continued)

Compound	Propellant	Primary or Initiator	Booster	Burster Charge	Pyrotechnics	Incendiary
PETN			C	C		
Tetryl			C			
Picric acid				C		
Explosive D				C		
Tetrazene		C				
DEGDN	C					
Nitrocellulose	C					
2,4-Dinitrotoluene	C			C		
2,6-Dinitrotoluene	C			C		
Ammonium nitrate	C			C		
Nitroglycerine	C			C		
Lead azide		C				
Lead styphnate		C				
Mercury fulminate		C				
White phosphorus*					C	C
Perchlorates	C				C	
Hydrazine	C					
Nitroguanidine	C					

* Classified as a bursting smoke and incendiary.

Table 3-4 illustrates the chemical compounds used in munitions and their potential human health effects as provided by EPA's Integrated Risk Information System (IRIS), the National Library of Medicine's Toxicology Data Network (TOXNET) Hazardous Substances Data Bank, the Agency for Toxic Substances and Disease Registry (ATSDR), and material safety data sheets (MSDS).

Table 3-4. Potential Toxic Effects of Explosive Chemicals and Components on Human Receptors

Contaminant	Chemical Composition	Potential Toxicity/Effects
TNT	2,4,6-Trinitrotoluene $C_7H_5N_3O_6$	Possible human carcinogen, targets liver, skin irritations, cataracts.
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine $C_3H_6N_6O_6$	Possible human carcinogen, prostate problems, nervous system problems, nausea, vomiting. Laboratory exposure to animals indicates potential organ damage.
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine $C_4H_8N_8O_8$	Animal studies suggest potential liver and central nervous system damage.
PETN	Pentaerythritol tetranitrate $C_5H_8N_4O_{12}$	Irritation to eyes and skin; inhalation causes headaches, weakness, and drop in blood pressure.
Tetryl	2,4,6-Trinitrophenyl-N-methylnitramine $C_7H_5N_5O_8$	Coughing, fatigue, headaches, eye irritation, lack of appetite, nosebleeds, nausea, and vomiting. The carcinogenicity of tetryl in humans and animals has not been studied.
Picric acid	2,4,6-Trinitrophenol $C_6H_4N_3O_7$	Headache, vertigo, blood cell damage, gastroenteritis, acute hepatitis, nausea, vomiting, diarrhea, abdominal pain, skin eruptions, and serious dysfunction of the central nervous system.
Explosive D	Ammonium picrate $C_6H_6N_4O_7$	Moderately irritating to the skin, eyes, and mucous membranes; can produce nausea, vomiting, diarrhea, skin staining, dermatitis, coma, and seizures.
Tetrazene	$C_2H_6N_{10}$	Associated with occupational asthma; irritant and convulsants, hepatotoxin, eye irritation and damage, cardiac depression and low blood pressure, bronchial mucous membrane destruction and pulmonary edema; death.
DEGDN	Diethylene glycol dinitrate $(C_2H_4NO_3)_2O$	Targets the kidneys; nausea, dizziness, and pain in the kidney area. Causes acute renal failure.
2,4-Dinitrotoluene	$C_7H_7N_2O_4$	Exposure can cause methemoglobinemia, anemia, leukopenia, liver necrosis, vertigo, fatigue, dizziness, weakness, nausea, vomiting, dyspnea, arthralgia, insomnia, tremor, paralysis, unconsciousness, chest pain, shortness of breath, palpitation, anorexia, and loss of weight.
2,6-Dinitrotoluene	$C_7H_7N_2O_4$	Exposure can cause methemoglobinemia, anemia, leukopenia, and liver necrosis.
Diphenylamine	N,N-Diphenylamine $C_{12}H_{11}N$	Irritation to mucous membranes and eyes; pure substance toxicity low, but impure material may contain 4-biphenylamine, a potent carcinogen.

Table 3-4. Potential Toxic Effects of Explosive Chemicals and Compounds on Human Receptors (continued)

Contaminant	Chemical Composition	Potential Toxicity/Effects
N-Nitrosodiphenylamine	$C_{12}H_{10}N_2O$	Probable human carcinogen based on an increased incidence of bladder tumors in male and female rats and reticulum cell sarcomas in mice, and structural relationship to carcinogenic nitrosamines.
Phthalates	Various	An increase in toxic polyneuritis has been reported in workers exposed primarily to dibutyl phthalates; otherwise very low acute oral toxicity with possible eye, skin, or mucous membrane irritation from exposure to phthalic anhydride during phthalate synthesis.
Ammonium nitrate	NH_4NO_3	Prompt fall in blood pressure; roaring sound in the ears with headache and associated vertigo; nausea and vomiting; collapse and coma.
Nitroglycerine (Glycerol trinitrate)	$C_3H_5N_3O_9$	Eye irritation, potential cardiovascular system effects including blood pressure drop and circulatory collapse.
Lead azide	N_6Pb	Headache, irritability, reduced memory, sleep disturbance, potential kidney and brain damage, anemia.
Lead styphnate	$PbC_6HN_3O_8 \cdot CH_2O$	Widespread organ and systemic effects including central nervous system, immune system, and kidneys. Muscle and joint pains, weakness, risk of high blood pressure, poor appetite, colic, upset stomach, and nausea.
Mercury fulminate	$Hg(OCN)_2$	Inadequate evidence in humans for carcinogenicity; causes conjunctival irritation and itching; mercury poisoning including chills, swelling of hands, feet, cheeks, and nose followed by loss of hair and ulceration; severe abdominal cramps, bloody diarrhea, corrosive ulceration, bleeding, and necrosis of the gastrointestinal tract; shock and circulatory collapse, and renal failure.
White phosphorus	P_4	Reproductive effects. Liver, heart, or kidney damage; death; skin burns, irritation of throat and lungs, vomiting, stomach cramps, drowsiness.
Perchlorates	ClO_4^-	Exposure causes itching, tearing, and pain; ingestion may cause gastroenteritis with abdominal pain, nausea vomiting, and diarrhea; systemic effects may follow and may include ringing of ears, dizziness, elevated blood pressure, blurred vision, and tremors. Chronic effects may include metabolic disorders of the thyroid.
Hydrazine	N_2H_4	Possible human carcinogen; liver, pulmonary, CNS, and respiratory damage; death.
Nitroguanidine	$CH_4N_4O_2$	No human or animal carcinogenicity data available. Specific toxic effects are not documented.

3.4.2 Ecological Effects

As with human health effects, ecological effects from chemical compounds associated with munitions usage depend on a combination of factors: the toxicity of the compound itself, the pathway by which the compound gets to a receptor, the concentration to which a receptor is exposed, and the reaction of the particular receptor to the compound. Site-specific assessment of the potential for an ecological impact is necessary to understand the manner in which a particular ecosystem (e.g., a wetlands environment) makes munitions constituents available to potential receptors. Ultimate receptors may include not only animal species, but also their habitat, including terrestrial and aquatic plant life. In some cases the habitat may act to biologically remediate concentrations that may otherwise seem harmful.

Guidance documents are available to assist in the conduct of ecological risk assessment. In addition, the *Wildlife Exposure Factors Handbook* developed by the EPA provides data, references, and guidance for conducting exposure assessments for 35 common wildlife species potentially exposed to toxic chemicals in their environment.[54] A variety of exposure factors (e.g., feeding habits, body weight) are examined and organized to allow the calculation of the potential for exposure.

Research on ecological effects of munitions constituents has been varied and fragmented. Conservative screening levels of the most common munitions constituents have been developed based on literature searches of toxic effects on a variety of species. The general approach is to compile a number of studies on similar categories of species and extrapolate conservative screening estimates based on the results of this compiled research. Little of this data is generated from real-world environmental observations, and instead is often derived from laboratory studies evaluated as part of human health toxicity assessments. Toxicity data on amphibians and reptiles are in general less developed than those for birds and mammals.

Screening Benchmarks

As used in this discussion, *screening benchmarks* are very conservative levels of a chemical that can produce adverse effects in selected species. Practically speaking, these levels are extrapolated and applied to related species to provide conservative levels that, if exceeded, should trigger a site-specific ecological risk assessment. Exceedence of a screening level benchmark need not mean that the potential ecological threat is real, as a variety of site-specific and species-specific factors must be considered.

Two recent efforts to derive screening-level benchmarks for ecotoxicity data are worth particular attention. Oak Ridge National Laboratory (ORNL), under a project sponsored by the U.S. Army and EPA, has developed ecotoxicity screening criteria and benchmarks using available data on eight nitroaromatic compounds, including TNT, RDX, HMX, picric acid, and tetryl.[55] In addition USCHPPM (U.S. Army Center for Health Promotion and Preventive Munitions) has developed Wildlife Toxicity Assessments (WTAs) for military compounds such as TNT, RDX, and HMX.

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[54]U.S. EPA. Office of Research and Development. *Wildlife Exposure Factors Handbook*, EPA/600/R-93/187, December 1993.

[55]S. Talmage, D. Opresko, C. Maxwell, C. Welsh, M. Cretella, P. Reno, and F. Daniel. *Nitroaromatic Munition Compounds: Environmental Effects and Screening Values*. Review of Environmental Contamination Toxicology 161:1-156, 1999.

Table 3-5 presents a compilation of potential adverse effects that these compounds may have on wildlife according to the sources described in the preceding paragraphs.

Table 3-5. Potential Effects of Explosive Chemicals and Compounds on Ecological Receptors

Contaminant	Potential Toxicity and Ecological Effects
TNT	TNT can be taken up by plants from contaminated soil, including edible varieties of garden plants, aquatic and wetland plants and tree species. Male animals treated with high doses of TNT have developed serious reproductive system effects; signs of acute toxicity to TNT include ataxia, tremors, and mild convulsions.[a] Screening benchmarks of toxicity for mammalian and bird wildlife species have been developed by ORNL[b] and CHPPM.[c]
RDX	ATSDR studies conclude that RDX does not build up in fish or in people.[a] Public health assessments conducted at the Iowa AAP concluded that crops are not bioaccumulating RDX and that they are safe for human consumption. In addition, studies at other Army facilities and laboratory studies suggest that deer and cattle do not bioaccumulate RDX in their tissue.[d] However, research does conclude that RDX is taken up by plants from contaminated soils and could be a potential exposure route for herbivorous wildlife. Screening benchmarks of toxicity for mammalian and bird wildlife species have been developed by ORNL and CHPPM. [b,c]
HMX	Research conducted by the ATSDR conclude that it is not known if plants, fish, or animals living in contaminated areas build up levels of HMX in their tissues. It is unknown whether or not HMX can cause cancer or reproductive problems in animals.[a] Screening benchmarks of toxicity for mammalian wildlife species have been developed by ORNL and CHPPM.[b,c]
PETN	Screening benchmarks of toxicity for mammalian wildlife species have been developed by CHPPM. Toxicological effects to laboratory animals studies used to develop TRVs included weight loss, blood pressure and respiratory problems.[c]
Tetryl	Adverse effects on plant and animal species have been identified for this contaminant. The ATSDR cites that it is not known if tetryl builds up in fish, plants, or land animals, nor if it causes birth defects or carcinogenicity in wildlife.[a] Screening benchmarks of toxicity for mammalian wildlife species have been developed by ORNL and are in preparation by CHPPM.[b]
Picric acid	Adverse effects on plant and animal species have been identified for this contaminant. The ATSDR states that these compounds are not likely to build up in fish or people. Results of studies in laboratory rats and wildlife species, such as white footed mice show anemia effects on the blood, behavioral changes, and male reproductive system damage.[a] Screening benchmarks of toxicity for mammalian and bird wildlife species have been developed by ORNL and CHPPM. Data for toxicity to birds, amphibians or reptiles is unavailable.[c]
Explosive D	Unavailable
Tetrazene	Unavailable
DEGDN	Unavailable
2,4-Dinitrotoluene	According to the ATSDR profile, DNT can be transferred to plants by root uptake from contaminated water or soil. Animals exposed to high levels of DNT had lowered number of sperm and reduced fertility. Animals also showed a reduction in red blood cells, nervous system disorders, liver cancer and liver and kidney damage.[a] Screening benchmarks of toxicity for wildlife species are being prepared by CHPPM.
2,6-Dinitrotoluene	The ATSDR profile states that 2,6-DNT has the same effect as 2,4-DNT on biota.[a] Screening benchmarks of toxicity for wildlife species are in preparation by CHPPM.
Diphenylamine	Unavailable

Table 3-5. Potential Effects of Explosive Chemicals and Compounds on Ecological Receptors (continued)

Contaminant	Potential Toxicity and Ecological Effects
N-Nitrosodiphenylamine	According to the ATSDR aquatic organisms take some n-nitrosodiphenylamine into their bodies, but they don't appear to build up high levels. It is not known if land animals or plants take it up and store it in their bodies. Animal studies have identified levels and exposures that can cause death. Animals given high levels of n-nitrosodiphenylamine in their diets for long periods of time developed swelling, cancer of the bladder, and changes in body weight.[a]
Phthalates	Unavailable
Ammonium nitrate	Unavailable
Nitroglycerine (Glycerol trinitrate)	Screening benchmarks of toxicity for mammalian and bird wildlife species have been developed by CHPPM. Mammalian effects included cardiovascular malfunction, decreased weight, and liver, blood, and reproductive problems.[c]
Lead azide	Unavailable
Lead styphnate	Unavailable
Mercury fulminate	Unavailable
White phosphorus	CRREL studies have shown that particles of white phosphorus that entered the bottom sediments of shallow ponds as a result of military training with white-phosphorus are highly toxic and contributed to the death of thousands of waterfowl at Eagle River Flats, Fort Richardson, AK.[a,e,f]
Perchlorates	Unavailable
Hydrazine	The ATSDR profile states hydrazines may build up in some fish living in contaminated water, but are not expected to remain at high levels over long periods of time. Tumors have been seen in many organs (lungs, blood vessels, and colon) of animals that were exposed to hydrazines by ingestion or breathing.[a]
Nitroguanidine	Unavailable

Notes:

[a]Data were taken from the toxicological profiles of these compounds prepared by the Agency for Toxic Substances and Disease Registry (ATSDR), Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, between 1993 and 1998.

[b]S. Talmage, D. Opresko, C. Maxwell, C. Welsh, M. Cretella, P. Reno, and F. Daniel. *Nitroaromatic Munition Compounds: Environmental Effects and Screening Values*. Prepared for Oak Ridge National Laboratory, Life Sciences Division, and the EPA National Exposure Research Laboratory, and published in Rev Environ Contam Toxicol 161:1-156, 1999.

[c]Data were taken from wildlife toxicity assessments performed for the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), Aberdeen Proving Ground, MD, 2001-2002.

[d]W.M. Weber and G. Campbell. Public Health Assessment, Iowa Army Ammunitions Plant, Middletown, Iowa. Federal Facilities Assessment Branch Division of Health Assessment and Consultation, CERCLIS No. IA7213820445, 1999.

[e]Data on white phosphorus were taken from C.H. Racine, M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, and L. Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munitions Residue*, and *White Phosphorus Contamination of Salt Marsh Pond Sediments at Eagle River Flats, Alaska*. USACE, Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH, May 1992.

[f]C.H. Racine, M.E. Walsh, C.M. Collins, S. Taylor, and B.D. Roebuck. *White Phosphorus Contamination of Salt Marsh Pond Sediments at Eagle River Flats, Alaska*. USACE, CRREL, Hanover, NH, May 1992.

3.4.3 Human and Ecological Effects from Exposure to Specific Compounds

This section further discusses known effects of specific compounds on human and ecological receptors.

White Phosphorus

One of the most frequently used bursting smoke fillers (also classified as an incendiary) is white phosphorus.[56] White phosphorus burns rapidly when exposed to oxygen. In soils with low oxygen, unreacted white phosphorus can lie dormant for years, but as soon as it is exposed to oxygen, it may react. If ingested, white phosphorus can cause reproductive, liver, heart, or kidney damage, or death. Skin contact can burn the skin or cause organ damage. White phosphorus has been found in fish caught in contaminated water and in game birds from contaminated areas.[57] Research conducted by CRREL has shown that an unusually high mortality of migratory waterfowl, particularly dabbling species such as ducks and swans, is attributable to the ingestion of elemental white phosphorus particles in the salt marsh sediments at Eagle River Flats, Alaska. Between 1982 and 1988, field and air surveys of the area were conducted. Nearly1,000 dead waterfowl were counted. The highest species-specific numbers included over 200 Northern pintail and over 150 Mallard ducks. Because of its use as an artillery training impact area (with nearly 7,000 rounds of white phosphorus fired in 1989), munitions contamination was suspected as the cause. Tissue studies of gizzard contents, fat tissue, liver, and kidneys found white phosphorus content in all field-collected ducks and swans analyzed. Behavior of exposed birds prior to death included increased thirst, head rolling, and violent convulsions.[58,59]

Trinitrotoluene (TNT)

TNT is soluble and mobile in surface water and groundwater. It is rapidly broken down into other chemical compounds by sunlight, and is broken down more slowly by microorganisms in water and sediments. TNT is not expected to bioaccumulate under normal environmental conditions. Human exposure to TNT may result from breathing air contaminated with TNT and TNT-contaminated soil particles stirred up by wind or construction activities. Workers in explosive manufacturing who are exposed to high concentrations of TNT in workplace air experience a variety of organ and immune system problems, as well as skin irritations and cataracts. Both EPA and ATSDR have identified TNT as a possible human carcinogen.

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[56]Joint Technical Bulletin, Department of Defense Ammunition and Explosive Classification Procedures, 5 January 1998, (TB 700–2/NAVSEAINST 8020.8B/TO 11A-1-47/DLAR 8220.1

[57]ATSDR. Toxicological Profile for White Phosphorous. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1997.

[58]C.H. Racine, M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, and L. Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munitions Residue*. Hanover, NH: USACE, Cold Regions Research and Engineering Lab, May 1992.

[59]C.H. Racine, M.E. Walsh, C.M. Collins, S. Taylor, and B.D. Roebuck. *White Phosphorus Contamination of Salt Marsh Pond Sediments at Eagle River Flats, Alaska*. Hanover, NH: USACE, CRREL, May 1992.

Toxicological Profiles of RDX and TNT

EPA's IRIS uses a weight-of-evidence classification for carcinogenicity that characterizes the extent to which the available data support the hypothesis that an agent causes cancer in humans. IRIS classifies carcinogenicity alphabetically from A through E, with Group A being known human carcinogens and Group E being agents with evidence of noncarcinogenicity. IRIS classifies both TNT and RDX as Group C, possible human carcinogens, and provides a narrative explanation of the basis for these classifications.[60]

The ATSDR is tasked with preventing exposure and adverse human health effects and diminished quality of life associated with exposure to hazardous substances from waste sites, unplanned releases, and other sources of pollution present in the environment.

The ATSDR has developed toxicological profiles for RDX and TNT to document the health effects of exposure to these substances. The ATSDR has identified both TNT and RDX as possible human carcinogens.[61]

The ecological impacts of TNT include blood, liver, and immune system effects in wildlife. In addition, in laboratory tests, male test animals treated with high doses of TNT developed serious reproductive system effects.

Research has concluded that RDX, TNT, and other nitroaromatic compounds can be accumulated by plants from contaminated soils and could be a potential exposure route for herbivorous wildlife. Plant studies conducted using TNT-contaminated soil taken from ammunition sites found a direct correlation between concentrations in soil and plants. Large-scale uptake of TNT was found to take place in plants, including edible varieties such as lettuce, beans, and carrots. Studies suggest that because of the prevalence of TNT-contaminated sites, risk assessors should consider the hazard posed to organisms higher in the food chain, including humans and wildlife, which could also be affected by exposure. In addition, seed germination and growth studies conducted on terrestrial higher plants found varied thresholds for phytotoxicity. Some plants (e.g., oat plants) have shown such high tolerances for TNT that they have been considered potential bioremediation species.[62]

Research Demolition Explosive (RDX)

RDX, also known as Research Demolition Explosive, is another frequently found synthetic explosive chemical. RDX dissolves in and evaporates from water very slowly. RDX does not bind

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[60]*Carcinogenicity Assessment for Lifetime Exposure of Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and Carcinogenicity Assessment for 2,4,6-trinitrotoluene (TNT) for Lifetime Exposure*, EPA Integrated Risk Information System, 1993.

[61]Agency for Toxic Substances and Disease Registry. *Toxicological Profile for 2,4,6-trinitrotoluene (update), and Toxicological Profile for RDX*, U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA, 1995.

[62]K. Schneider, J. Oltmanns, T. Radenberg, T. Schneider, and D. Pauly-mundegar. *Uptake of Nitroaromatic Compounds in Plants: Implications for Risk Assessment of Ammunition Sites*. Environmental Science and Pollution Research International 3(3)135-138, 1996.

well to soil particles and can migrate to groundwater, but the rate of migration depends on the soil composition. If released to water, RDX is degraded mainly by direct photochemical degradation that takes place over several weeks. RDX does not biologically degrade in the presence of oxygen, but anaerobic degradation is a possible fate process under certain conditions. RDX's potential for bioaccumulation is low. Human exposure to RDX results from breathing dust with RDX particles in it, drinking contaminated water, or coming into contact with contaminated soils. RDX inhalation or ingestion can create nervous system problems and possibly organ damage. As discussed previously, RDX has been identified as a possible human carcinogen.

The ecological effects of RDX suggested by laboratory studies include neurological damage including seizures and behavioral changes in wildlife that ingest or inhale RDX. Wildlife exposure to RDX may also cause damage to the liver and the reproductive system.

3.5 Other Sources of Conventional Munitions Constituents

Contamination of soils and groundwater with explosive compounds results from a variety of activities. These activities include the release of other munitions constituents during planned munitions training and testing, munitions disposal/burial pits associated with military ranges, and munition storage sites and build-up locations. Contamination may also result from the deterioration of intact munitions, the open burning and open detonation of munitions, and the land disposal of explosives-contaminated process water from explosives manufacturing or demilitarization plants. Munitions constituents include heavy metals, particularly lead and mercury, because they are components of primary or initiating explosives such as lead azide and mercury fulminate. These metals are released to the environment after a detonation or possibly by leaching out of damaged or corroded munitions. The sections below describe specific sources of munitions constituents.

3.5.1 Open Burning/Open Detonation (OB/OD)

Concentrations of munitions constituents, such as explosives and metals, and bulk explosives have been found at former OB/OD areas at levels requiring a response. OB/OD operations are used to destroy excess, obsolete, or unserviceable munitions and energetic materials. OB operations employ self-sustained combustion, which is ignited by an external source. In OD operations, explosives and munitions are destroyed by a detonation, which is normally initiated by the detonation of an energetic charge. In the past, OB/OD operations have been conducted on the land surface or in shallow burn pits. More recently, burn trays and blast boxes have been used to help control and contain emissions and other contamination resulting from OB/OD operations. See Chapter 5 for a fuller discussion of OB/OD.

Incomplete combustion of munitions and energetic materials can leave uncombusted TNT, RDX, HMX, PETN, and other explosives. These materials can possibly be spread beyond the immediate vicinity of the OB/OD operation by the kick-out these operations generate and can contribute to potentially adverse human health and ecological effects.

3.5.2 Explosives Manufacturing and Demilitarization

Explosives manufacturing and demilitarization plants are also sources of munitions constituents. These facilities are usually commercial sites that are not usually co-located with defense sites. Many of these facilities have contaminated soils and ground-water. The manufacture; load, assemble, and pack operations; and demilitarization of munitions create processing waters that in the past were often disposed of in unlined lagoons, leaving munitions constituents behind after infiltration and evaporation.

> **Demilitarization of Munitions**
>
> Demilitarization is the processing of munitions so they are no longer suitable for military use.
>
> Demilitarization of munitions involves several techniques, including both destructive and nondestructive methods. Destructive methods include OB/OD and incineration. Nondestructive methods include the physical removal of explosive components from munitions. Munitions are generally demilitarized because they are obsolete or their chemical components are deteriorated.

Red water, the effluent from TNT manufacturing, was a major source of munitions constituents in soils and groundwater at army ammunition plants. TNT production ended in the mid-1980s in the United States; however, contamination of soils and groundwater from red water remains in some areas.

In the demilitarization operations conducted up to the 1970s, explosives were removed from munitions with jets of hot water or steam. The effluent, called pink water, flowed into settling basins, and the remaining water was disposed of in unlined lagoons or pits, often leaving highly concentrated munitions constituents behind. In more advanced demilitarization operations developed in the 1980s, once the solid explosive particles settled out of the effluent, filters such as diatomaceous earth filters and activated carbon filters were employed to further reduce the explosive compounds, and the waters were evaporated from lagoons or discharged into water systems.

3.6 Conclusions

The potential for explosive damage by different types of MEC, including buried munitions, UXO, and munitions constituents, depends on many different factors. These factors include the magnitude of the potential explosion, the sensitivity of the explosive compounds and their breakdown products, fuze sensitivity, the potential for deflagration or detonation, the potential for MEC deterioration, and the likelihood that the item will be disturbed, which depends on environmental and human activities.

MEC items may also present other human health, ecological and environmental risks, depending on the state of the item. Specifically, a MEC item that is degraded may release propellants, explosives, pyrotechnics, and other munitions constituents into the surrounding area, thereby potentially contaminating the environment and affecting human health. Other human health and environmental risks may result from the explosives and from other chemicals used or produced in munitions operations such as OB/OD; manufacturing; demilitarization; and load, assemble, and pack operations.

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

Agency for Toxic Substances and Disease Registry (ATSDR). ***Toxicological Profile for 1,3-dinitrobenzene/1,3,5-trinitrobenzene (update)***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1995.

ATSDR. ***Toxicological Profile for 2,4,6-trinitrotoluene (update)***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1995.

ATSDR. ***Toxicological Profile for 2,4- and 2,6-dinitrotoluene***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1998.

ATSDR. ***Toxicological Profile for HMX***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1997.

ATSDR. ***Toxicological Profile for Hydrazines***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1997.

ATSDR. ***Toxicological Profile for n-nitrosodiphenylamine***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1993.

ATSDR. ***Toxicological Profile for RDX***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1995.

ATSDR. ***Toxicological Profile for Tetryl (update)***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1995.

ATSDR. ***Toxicological Profile for White Phosphorous***. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1997.

Bailey, A., and S.G. Murray. ***Explosives, Propellants and Pyrotechnics***. Brassey's (UK) Ltd., 1989.

Bucci, J.E., and P.F. Buckley. ***Modeling the Degradation of Unexploded Ordnance (UXO) and Its Use as a Tool in the Development of Risk Assessments***. Paper presented at the UXO Forum 1998. Available at http://uxocoe.brtrc.com/UXOForumDocs/Forum98/Bucci.pdf.

Cooper, P.W. ***Explosives Engineering***. New York, NY: Wiley-VCH, 1996.

Crockett, A.B., H.D. Craig, and T.F. Jenkins. ***Field Sampling and Selecting On-site Analytical Methods for Explosives in Water***. U.S. EPA Federal Facilities Forum Issue, May 1999, EPA/540/R-97/501.

Crull, M.L., L. Taylor, and J. Tipton. ***Estimating Ordnance Penetration Into Earth***. Paper presented at UXO Forum 1999, Atlanta, GA., May 25-27, 1999.

Federal Advisory Committee for the Development of Innovative Technologies. ***Unexploded Ordnance (UXO): An Overview***. U.S. Navy, Naval Explosive Ordnance Disposal Technology Division, UXO Countermeasures Department, Oct. 1996.

Johnson, M.S., and J.J. McAtee. ***Wildlife Toxicity Assessment for 2,4,6 5-trinitrotoluene***. U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) Project Number 39-EJ-1138-00. Aberdeen Proving Ground, MD, Oct. 2000.

Kleine, H., and A. Makris. ***Protection Against Blast Effects in UXO Clearance Operations***. UXO Forum 1999 Proceedings, 1999.

Racine, C.H., M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, and L. Reitsma. ***Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munitions Residue***. Hanover, NH: USACE, Cold Regions Research and Engineering Lab, May 1992.

Racine, C.H., M.E. Walsh, C.M. Collins, S. Taylor, and B.D. Roebuck, ***White Phosphorus Contamination of Salt Marsh Pond Sediments at Eagle River Flats, Alaska***. Hanover, NH: USACE, CRREL, May 1992.

Roberts, W.C., and W.R. Hartley. ***Drinking Water Health Advisory: Munitions***. Boca Raton, FL: Lewis Publishers, 1992.

Schneider K., J. Oltmanns, T. Radenberg, T. Schneider, and D. Pauly-mundegar. ***Uptake of Nitroaromatic Compounds in Plants: Implications for Risk Assessment of Ammunition Sites***. Environmental Science and Pollution Research International 3(3)135-138, 1996.

Talmage S., D. Opresko, C. Maxwell, C. Welsh, M. Cretella, P. Reno, and F. Daniel. ***Nitroaromatic Munition Compounds: Environmental Effects and Screening Values***. Review of Environmental Contamination and Toxicology 161:1-156, 1999.

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), ***Standard Practice for Wildlife Toxicity Reference Values***, Technical Guide 254 (USACHPPM TG 254), Environmental Health Risk Assessment Program and Health Effects Research Program, Aberdeen Proving Ground, MD, Oct. 2000.

Wildlife Toxicity Assessment for 1,3,5-trinitrobenzene. U.S. Army Center for Health Promotion and Preventive Medicine (CHPPMUSA) Project Number 39-EJ-1138-01B, Aberdeen Proving Ground, MD, Nov. 2001.

Wildlife Toxicity Assessment for 1,3,5-trinitrohexahydro-1,3,5- triazine (RDX). U.S. Army Center for Health Promotion and Preventive Medicine (CHPPMUSA) Project Number 39-EJ-1138-01B, Aberdeen Proving Ground, MD, May 2002.

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). ***Wildlife Toxicity Assessment for HMX***, Project Number 39-EJ-1138-01E, Aberdeen Proving Ground, MD, Oct. 2001.

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). ***Wildlife Toxicity Assessment for Nitroglycerin***, Project Number 39-EJ-1138-01F, Aberdeen Proving ground, MD, Oct. 2001.

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). ***Wildlife Toxicity Assessment for Pentaerythritol Tetranitrate (PETN)***, Project Number 37-EJ-1138-01G, Aberdeen Proving Ground, MD, Nov. 2001.

U.S. Army Corps of Engineers. ***Ordnance and Explosives Response: Engineering and Design***. No. 1110-1-4009, June 23, 2000.

U.S. Department of Defense, Office of the Under Secretary of Defense (Acquisition and Technology). ***Report to Congress, Unexploded Ordnance Clearance: A Coordinated Approach to Requirements and Technology Development***. Joint Unexploded Ordnance Clearance Steering Group, Mar. 25, 1997.

U.S. Environmental Protection Agency (U.S. EPA). ***Handbook: Approaches for the Remediation of Federal Facility Sites Contaminated With Explosive or Radioactive Wastes***. EPA/625/R-93/013, Sept. 1993.

U.S. EPA, Criteria and Standards Division, Office of Drinking Water. ***Health Advisory for Hexahydro-1,3,5-Trinitro-1,3,5-Triazine (RDX)***. Nov. 1988.

U.S. EPA, Office of Drinking Water. ***Health Advisory for Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)***. NTIS No. SPB90-273525. Nov. 1988.

U.S. EPA, Office of Drinking Water. ***Health Advisory for 2,4,6–Trinitrotoluene,*** Jan. 1989.

U.S. EPA, Office of Research and Development, ***Wildlife Exposure Factors Handbook***. EPA/600/R-93/187, Dec. 1993.

Weber, W.M., and G. Campbell. ***Public Health Assessment, Iowa Army Ammunitions Plant***. Middletown, Iowa, Federal Facilities Assessment Branch, Division of Health Assessment and Consultation, CERCLIS No. IA7213820445, 1999.

Wilcher, B.L., D. Eisen, and R. Booth. ***Evaluation of Potential Soil Contamination from Open Detonation During Ordnance and Explosives Removal Actions, Former Fort Ord, California***. Paper presented at UXO Forum 1999, Atlanta, GA, May 25-27, 1999.

Information Sources

Department of Defense Explosives Safety Board (DDESB)
2461 Eisenhower Avenue
Alexandria, VA 22331-0600
Fax: (703) 325-6227
http://www.ddesb.pentagon.mil

ORDATA II (database of ordnance items)
Available from: NAVEOTECHDIV
Attn: Code 602
20008 Stump Neck Road
Indian Head, MD 20640-5070
E-mail: ordata@eodpoc2.navsea.navy.mil

U.S. Department of Health and Human Services, Public Health Service
Agency for Toxic Substances and Disease Registry (ATSDR)
Division of Toxicology
1600 Clifton Road, E-29
Atlanta, GA 20222
http://www.atsdr.cdc.gov

U.S. Environmental Protection Agency, Technology Innovation Office
Hazardous Waste
Cleanup Information (CLU-IN)
http://www.clu-in.org/

U.S. Environmental Protection Agency
Integrated Risk Information System (IRIS)
U.S. EPA Risk Information Hotline
Tel: (513) 569-7254
Fax: (513) 569-7159
E-mail: RIH.IRIS@epamail.epa.gov
http://www.epa.gov/ngispgm3/iris/index.html

U.S. Army Corps of Engineers
U.S. Army Engineering and Support Center
Ordnance and Explosives Mandatory Center of Expertise
P.O. Box 1600
4820 University Square
Huntsville, AL 35807-4301
http://www.hnd.usace.army.mil/

4.0 DETECTION OF UXO AND BURIED MUNITIONS

4.1 Introduction

Geophysical detection technologies are deployed in a nonintrusive manner to locate surface and subsurface anomalies that may be UXO or buried munitions. (For purposes of brevity, discussions of UXO and buried munitions will be referred to as MEC throughout this chapter.) Proper selection and use of these technologies is an important part of the site investigation, which often takes place on ranges or parts of ranges that cover many acres. Since excavating all the land to depth is usually not practical, MEC detection technologies are used to locate anomalies that are subsequently verified as UXO or non-UXO. Given the high cost of MEC excavation (due to both range size and safety considerations), the challenge of most MEC investigations is the accurate and appropriate deployment of nonintrusive geophysical detection technologies to maximize probability of detection and minimize false alarms.

Since the early 1990s, existing geophysical survey technologies have improved in their capabilities to efficiently and cost-effectively detect MEC. Much of the improvement is the result of greater understanding of operational requirements for the use of detection technologies. However, the primary challenge in MEC detection today is the achievement of high levels of subsurface detection of actual MEC in a consistent, reproducible manner with a high level of quality assurance. Distinguishing ordnance from fragments and other nonordnance materials based solely on the geophysical signature, called target discrimination, is also a major challenge in MEC detection and the focus of research and development activities. This problem is known as a **false alarm**, as described in the text box below. Poor discrimination results in lower probability of detection, higher costs, longer time frames for cleanups, and potentially greater risks following cleanup actions.

False Alarms

The term *false alarm* is used when a declared UXO detection location does not correspond to an actual UXO location based upon the groundtruth data. **False positives** are anomalous indications where nothing is found that caused the instrument to detect an anomaly at that location. False positives can result in incorrect estimations of UXO density and often lead to expensive or unnecessary excavation of an anomaly if it is not UXO. Depending on the site-specific conditions, as few as 1 percent of anomalies may actually be UXO items. Because of the difficulty, danger, and time required to excavate UXO, high costs per acre are exacerbated by a high false positive rate. **False negatives** occur when ordnance items are not detected by the geophysical instrument used or are misidentified in post-processing, resulting in potential risks remaining following UXO investigations.

It should be noted that a particular technology or combination of technologies will never have the highest effectiveness, best implementability, and lowest cost at every site. In other words, there is no "silver bullet" detection technology. It is also important to note that no existing technology or combination of existing technologies can guarantee that a site is completely MEC-free. As discussed in Section 4.2 below and in Chapter 7, a combination of information from a variety of sources (including historical data, results of previous environmental data collection, and knowledge of field and terrain conditions) will be used to make decisions about the detection system to be used, including the particular sensor(s), the platform on which it is deployed, and data acquisition and processing techniques. Detailed fact sheets on each of the detection sensors currently in use are found at the end of this chapter.

Experts in the MEC research and development community have indicated that currently available detection technologies will improve with time and that no revolutionary new systems are likely to be developed that uniformly improve all MEC detection. Much of the performance improvement of current detection technologies has come from a better understanding of how to use the technologies and from the use of combinations of technologies at a site to improve anomaly detection rates. Current improvements in detection systems generally focus on discriminating ordnance from nonordnance. Emerging processing and numerical modeling programs will enhance the target discrimination capabilities of detection systems. In general, these programs rely on identifying UXO and clutter based on their "signatures" (e.g., spatial pattern of magnetic signal).

Geophysical sensors have specific capabilities and limitations that must be evaluated when selecting a detection system for a site. The primary types of sensors in use today are:

- **Magnetometry** — a passive sensor that measures a magnetic field. Subsurface ferrous items create irregularities in the Earth's magnetic field and may contain remnant magnetic fields of their own that are detected by magnetometers.
- **Electromagnetic Induction (EMI)** — an active sensor that induces electrical currents beneath the earth's surface. Conductivity readings of the secondary magnetic field created by the electrical currents are used to detect both ferrous and nonferrous ordnance items.

In addition, under specific and limited conditions, ground-penetrating radar (GPR) has been successfully used to detect MEC. This sensor is mainly helpful when the location of larger munitions burial sites is known and boundaries must be identified. Magnetometers, EMI sensors, and GPR sensors are discussed in detail in Section 4.2 and in the fact sheets at the end of the chapter. The results of investigations using any sensor can vary dramatically depending not only on the site conditions, but also on the components of the detection system, the skill of the operator, and the processing method used to interpret the data.

Detection systems that will be available in the near future include advanced electromagnetic systems and airborne magnetometers. Long-term research endeavors include a GPR that can identify UXO at discrete locations, and an airborne EMI sensor. An overview of emerging detection technologies, as well as data processing and modeling for target discrimination, is presented in Sections 4.3 and 4.4.

In response to the stagnancy of detection technology development at the beginning of the Base Realignment and Closure (BRAC) Program, the U.S. Congress established the Jefferson Proving Ground Technology Demonstration (JPGTD) program in Madison, Indiana. The JPGTD program was established to demonstrate and promote advanced and innovative UXO systems that are more cost-efficient, effective, and safer. In the program, vendors of geophysical systems were invited to test and compare the efficiency and reliability of the systems. It is important to note that the test did not look at the process by which the system was deployed and was not structured to determine why certain approaches worked better than others. In subsequent phases of the JPGTD program, vendors improved the processes by which sensors were deployed, and significantly improved their detection rates. The JPGTD and other demonstration programs, such as the Environmental Security Technology Certification Program UXO Technology Standardized Demonstration Sites and the Fort Ord Ordnance Detection and Discrimination Study (ODDS), are discussed in Section 4.5.

4.2 Selection of the Geophysical Detection System

Many factors should be considered when identifying the detection system appropriate to your site. First, information about the detection sensors currently available, and the factors that contribute to their successful application, should be evaluated. Next, basic site conditions should be evaluated, such as expected targets (size, location, density, depths), terrain, vegetation, and electromagnetic fields. Finally, the role of each system component and how it affects overall performance should be examined to ensure maximum effectiveness.

4.2.1 Geophysical Sensors in Use Today

Magnetometry and electromagnetic induction are the most frequently used sensors for detecting MEC. Both sensors are commercially available and are employed on a variety of systems using various operational platforms, data processing techniques, and geolocation devices.

4.2.1.1 *Electromagnetic Induction (EMI)*

EMI sensors are perhaps the most widely used systems for detecting MEC. The electromagnetic induction system is based on physical principles of inducing and detecting electrical current flow within nearby conducting objects. EMI surveys work by inducing time-varying magnetic fields in the ground from a transmitter coil. The resulting secondary electromagnetic field set up by ground conductors is then measured at a receiver coil. EMI systems can detect all conductive materials but are at times limited by interference from surface or near-surface metallic objects. In general, the EMI response will be stronger the closer the detector head is to the buried target, but close proximity to the ground surface may subject the sensor to interference from shallow fragments. In areas of heavy vegetation, the distance between the detector head and the earth's surface is increased, potentially decreasing signal strength and decreasing the probability of detection. Soil type also plays a role in EMI system detection. EMI systems may have difficulty detecting small items in conductive soils, such as those containing magnetite, or in soils with cultural interferences, such as buildings, metal fences, vehicles, cables, and electrical wires. Because the difficulties with detecting small items in conductive soils are also present for magnetometry, this issue is usually not a limiting factor in selection of an EMI system.

EMI systems operate in time or frequency domains. Time-domain electromagnetic (TDEM) systems operate by transmitting a magnetic pulse that induces currents in and near conducting objects. These currents produce secondary magnetic fields that are measured by the sensor after the transmitter pulse has ended. The sensor integrates the induced voltage over a fixed time gate and averages over the number of pulses. When

EMI and Electronic Fuzes

EMI is an active system for which there has been concern about increasing the risk of initiating MEC with electronic fuzing. However, there is no evidence that the current generation of EMI-based systems, when used in accordance with the manufacturer specifications (e.g., EM-61), generate enough power to cause this effect. This may be an issue to watch in the future, however, if more powerful systems are developed.

TDEM detectors are hand-held or smaller they may have less penetration depth than the more commonly used large-coil EMI.

Frequency-domain electromagnetic (FDEM) instruments operate by transmitting continuous electronic signals and measuring the resulting eddy currents. FDEM instruments are able to detect deeply buried munitions that are grouped together. In addition, some types of FDEM instruments are capable of detecting very small individual MEC items that are buried just beneath the ground surface, such as metal firing pins in plastic land mines. FDEM instruments are currently not typically used when detecting individual, deeply buried munitions, because of the sensor's decreased resolution and the difficulty of measuring the amplitude of return of individual targets.

4.2.1.2 *Magnetometry*

Magnetometers are passive systems that use the Earth's magnetic field as the source of the signal. Magnetometers detect distortions in the magnetic field caused by ferrous objects. The magnetometer has the ability to detect ferrous items to a greater depth than can be achieved by other systems. Magnetometers can identify small anomalies because of the instrument's high levels of sensitivity. However, magnetometers are also sensitive to many iron-bearing minerals and "hot rocks" (rocks with high iron content), which affects the detection probability by creating false positives and masking signals from real ordnance.

The two most common magnetometry systems used to detect buried munitions are cesium vapor or fluxgate. Cesium vapor magnetometers measure the magnitude of a magnetic field. These systems produce digital system output. The fluxgate systems measure the relative intensity of the gradient in the Earth's magnetic field. These systems are inexpensive, reliable, and rugged and have low energy consumption.

4.2.1.3 *Multisensor Systems*

Multisensor systems combine two or more sensor technologies in order to improve UXO detection performance. The technologies that have proved to be most effective in multisensor systems are arrays of full-field cesium vapor magnetometers and time-domain EMI pulsed sensors. Multisensor systems can enhance detector performance by providing complementary data sets that can be used to confirm the presence of MEC.

Multisensor systems are available both as man-portable configurations and as linear arrays on platforms that do not themselves produce a significant geophysical signature while they tow the array over survey sites by all-terrain vehicles.

4.2.1.4 *Ground Penetrating Radar*

GPR is another sensor technology that is currently commercially available, although it is not used as frequently as EMI and magnetometry and is generally not as reliable. GPR systems use high-frequency (approximately 10 to1,000 MHz) electromagnetic waves to excite the conducting object, thus producing currents. The currents flow around the object, producing electromagnetic fields that radiate from the target. The signals are received by the GPR antenna and stored for further processing. Most commercial systems measure total energy return and select potential targets based on contrast from background. More advanced processing uses the radar information to produce two-or three-dimensional images of the subsurface or to estimate features of the target, such as length or a spectra. Such processing systems are not generally in use at this time.

The GPR system is more accurate when used in areas of dry soil. Water in the soil absorbs the energy from the GPR, thus interfering with UXO detection. GPR may be used to find the boundaries of large caches of buried munitions. Because the GPR system uses active electromagnetic waves to locate buried objects, there is concern that electronic fuzes on MEC items could be initiated by these systems. As with EMI, there is no evidence that deployment of GPR has initiated electronic fuzes during MEC investigations.

4.2.2 Selection of the Geophysical Detection System

The selection of a detection system is a site-specific decision. Some of the factors that should be considered in selecting a detection system include, but are not limited to, the following:

- Site size
- Soil type, vegetation, and terrain
- Subsurface lithology
- Depth, size, shape, composition, and type of MEC
- Geological and cultural noise (e.g., ferrous rocks and soils, electromagnetic fields from power lines)
- Non-MEC clutter on-site
- Historical land use
- Reasonably anticipated future land use
- MEC density

Each of the above factors should be considered against the decision goals of the investigation in order to select the most appropriate detection system. Table 4-1 highlights the effects of each factor on the investigation process. This list of considerations is not all-inclusive.

Table 4-1. Examples of Site-Specific Factors To Be Considered in Selecting a Detection System

Site Factors	Considerations
Site size	Different operational platforms cover areas at different speeds. If a large area needs to be surveyed, operational platforms such as towed-array or airborne may be considered, if appropriate.
Soil properties	Potential for high conductivity levels to interfere with target signals; potentially reduced detection capabilities using magnetometers in ferrous soils.
Vegetation	Heavy vegetation obstructs view of MEC items on surface and may interfere with sensor's ability to detect subsurface anomalies, as well as access to the site and operation of the sensor.
Terrain	Easily accessible areas can accommodate any operational platform; difficult terrain may require man-portable platform.
Subsurface lithology	Soil and rock layers and configurations beneath the ground surface will influence the depth of the UXO and the ability of the sensor to "see" anomalies.
Target size and orientation	Capability of detector to find objects of various sizes and at various orientations.
Target penetration depth	Capability of detector to find targets at depths. Potential for decreased signal when detecting deeply buried targets.
Composition of UXO	Projectile and fuze composition may dictate sensor selection. Magnetometers detect only ferrous materials, while EMI systems detect all metals.
Noise	Both geological noise (e.g., hot rocks or high ferrous content in soil) and cultural noise (e.g., buried cables, overhead utilities) potentially increase false alarms and mask ordnance signals.
Non-UXO clutter	Potential difficulty discriminating between small objects and metallic scrap, resulting in high numbers of false alarms.
Historical land use	Information about expected target location, types, and density.
Future land use	Enables setting of realistic decision goals for investigation.
UXO density	Enables sensor strengths (e.g., ability to see individual items as opposed to large caches of targets) to be maximized.

DoD/EPA Management Principles on Detection Technologies

EPA and DoD identified the critical metrics for evaluating the performance of a detection technology as the **probabilities of detection and false alarms**. Specifically, they call for the performance evaluation of detection technologies to consider the following factors:

- Types of munitions
- Size of munitions
- Depth distribution of munitions
- Extent of clutter
- Environmental factors (e.g., soil, terrain, temperature, and vegetation)

"The performance of a technology cannot be properly defined by its probability of detection without identifying the corresponding probability of false alarms. Identifying solely one of these measures yields an ill-defined capability. Of the two, probability of detection is a paramount consideration in selecting a UXO detection technology."

4.2.3 MEC Detection System Components

Table 4-2 identifies the various elements of a detection system and highlights how each element may affect the overall system performance. For example, the three operational platforms — man-held, towed-array, and airborne — directly affect the sensor's distance from the target, which, in turn, affects the sensor's ability to detect targets. The ability of all sensors to "see" targets decreases as distance from the target increases. However, the rate at which the performance drops off with distance varies by individual sensor. An additional consideration when selecting the operational platform includes what is expected to be found beneath the surface. Large caches of munitions buried deep beneath the surface may remain detectable from large distances, whereas smaller items may be more easily missed by the sensor at a distance.

Table 4-2. System Element Influences on Detection System Performance

System Element	Factors To Be Considered
Geophysical sensor	Site-specific conditions and the results of the geophysical prove-out are used to determine the sensor and system configuration best suited to achieve the goals of the investigation.
Positioning system	Accuracy and precision in positioning and navigation are needed to locate targets in relation to coordinate systems. Tree cover, terrain, and need for line of sight may restrict choices.
Geophysical prove-out	The accuracy with which geophysical prove-out represents field conditions and sampling methods helps to ensure the development of data with a known level of certainty in field operations.

Table 4-2. System Element Influences on Detection System Performance (continued)

System Element	Factors To Be Considered
Operator capability	The selection and use of detection systems is complex and requires individuals with appropriate qualifications and experience. Qualification of the geophysical team to meet prove-out performance is a recommended QA/QC measure.
Operational platform	Size and depth of ordnance, sensor sensitivity to height above target, and potential for interference with sensor operation by platform components, and terrain and vegetation restriction need to be taken into account when selecting a platform.
Data acquisition	Digital versus analog data, reliability of data points, and ability to merge geophysical signals with a positioning system (e.g., GPS) data affect potential for human error.
Data analysis	Experienced and qualified analysts and appropriate procedures help to ensure reliability of results.

Operational Platforms for UXO Detection Systems

- **Man-Portable** – Man-portable systems can be used in areas that cannot be accessed by other platforms, such as those with heavy vegetation or rough terrain. The use of man-portable systems generally requires extensive man-hours, as the maximum speed with which the system can be operated is that at which an operator can walk the sampling area.

- **Towed Array** – These systems are generally used in flat treeless areas and can cover a larger area using fewer man-hours. Limitations include the inability to use towed-array systems in heavily wooded areas, other areas inaccessible to vehicles, or urban areas with tall buildings.

- **Airborne** – These systems are used to survey large, flat, treeless areas in a short period of time, using current magnetometry sensors requiring minimal standoff. Airborne systems can be very useful in detecting larger objects such as those that may be found in a bombing range. They can be highly cost-effective on large ranges because of the amount of acreage that can be covered and the resulting low cost per acre. In limited use today, airborne platforms are not as widely used as the other platforms. The disadvantage of airborne detection is the high cost of the hardware and potential difficulty of penetrating deep enough below the ground surface, which is a function of both the altitude at which aircraft must fly, as well as of the sensor used.

4.2.3.1 *Positioning Systems*

Positioning systems are used to determine and record where a geophysical sensor is in relation to known points, such as how it is oriented and the pathway of its travel as it is collecting data. Knowing the location of the sensor will allow the geophysical analyst to estimate the location of subsurface anomalies that may be MEC. The accuracy of the positioning system will directly affect the ability of field teams to successfully relocate and excavate subsurface anomalies. The performance of the positioning system used on your project should be assessed at the same time that the performance of the geophysical sensor is assessed.

All positioning systems rely on determining the location of the geophysical sensor in relation to a known point or points. They also all provide a method for correlating the positional data with the geophysical sensor data. Commonly used positioning systems are shown in the table below.

Table 4-3. Description of Positioning Systems

Positioning System	Description
Differential Global Positioning System (DGPS)	C Triangulates the position of the Differential global positioning system receiver with respect to several satellites and terrestrial base stations C Can yield accuracy on the order of 20 cm. C Differential global positioning system signal can be blocked by heavy overhead tree canopy; satellite availability will also strongly influence accuracy. C Differential global positioning system receiver must be in close proximity to the geophysical sensor; with man-portable sensor configurations, the extra weight of the Differential global positioning system receiver and recorder (usually over 50 pounds) can increase personnel requirements during the performance of the geophysical survey.
Acoustic Ranging and Total Station Electronic Distance Meter (EDM)	C Calculates the distance between the receiver and a known point based on return time for either an acoustic or optical (infrared, laser) signal. C Accuracy depends on atmospheric and other conditions that may distort acoustic or optical signal. C Methods require a line of sight between receiver and known points.
Digital Thread	C Hybrid technology uses odometer wheel turned by survey thread; optical switch embeds position mark every 4-6 cm. C Works well in rugged, forested terrain.
"Dead Reckoning" Techniques	C Extrapolates current position from a previously know point by applying information on direction, speed, and time traveled. Locations determined by measurements from known points using survey tapes and trigonometry. C Highly dependent on the competence of the operator. C Assumes geophysical sensor has traveled in a straight line from a known point to the point of measurement.

4.2.3.2 *Anomaly Identification*

The geophysical sensor and positional data collected during the survey are analyzed to identify geophysical "anomalies," that is, readings that are different from the surrounding background. There are two steps to the anomaly identification process; data processing and data analysis. The quality of the anomaly identification process is critical to the performance of the geophysical detection system.

In general, data processing consists of the merging of the geophysical sensor and the positional data, and the creation of a map of the geophysical data. The output from this step should include the aforementioned map showing the locations of the sensor readings, a text narrative or a table describing the data acquisition parameters (e.g., sensor and positioning devices used, adjacent lane overlap for grids), and a narrative describing the data processing details (e.g., method used to synchronize geophysical and positional data, any signal filtering or background leveling applied). Digital outputs should include all raw data, field acquisition and data processing notes, and the merged database.

The primary objective of the data analysis step is to determine if a given geophysical anomaly meets the minimum threshold selection criteria of subsurface munitions. The determination of these selection criteria will be based on the geophysical sensor, the survey pattern, and the type of munitions under investigation, as well as the geological conditions and the analyst's experience. The output from this step should include a clear description of the selection criteria and the rationale for that criteria, a prioritized dig list with a unique identifier for each anomaly, the spatial location (the *x* and *y* coordinates) of each anomaly, and the metric attributes of each anomaly (e.g., the magnitude of the reading above background).

4.2.4 Costs of UXO Detection Systems

The factors influencing the costs of deploying MEC detection systems are complex, and much broader the simple rental or purchase of a detector or sensor. The entire life cycle of the response process and the nature of the detection system must be considered. Life-cycle issues include:

- Costs of capital equipment
- Acreage that can be covered by your detection system over a specific period of time
- Rate of false positives, and costs of unnecessary excavation
- Costs of rework if it is later proven that the system deployed resulted in a number of false negatives
- Required clearance of vegetation
- Costs of response
- Costs of operator salaries, based on the complexity and sophistication of the detection system (including training and certification of operators)

Evaluation of the factors may lead to site-specific decisions related to certain cost tradeoffs, for example:

- That high capital expenditures (e.g., airborne platforms) will result in reduced costs when large acreage is involved.
- Extensive use of expensive target discrimination equipment may be more worthwhile at

a transferring base where land uses are uncertain, and transfer will not occur until the property is "cleaned" for the particular use.

- For small acreage, equipment producing a high rate of false positives may be acceptable if excavation is less costly than extensive data processing.
- Investments in systems with sensitive detectors and extensive data processing may be considered worthwhile when the potential for rework, or for lack of acceptance of cleanup decisions, is considered.

4.2.5 Quality Assurance/Quality Control

As discussed in Chapter 8, a comprehensive quality assurance/quality control (QA/QC) process that addresses every aspect of the selection and use of geophysical detection equipment, as well as evaluation of findings, is absolutely essential. Specifically, data acquisition quality is a function of appropriate data management, including acquisition of data in the field, data processing, data entry, and more. In addition, field observation of data acquisition, reacquisition, and excavation procedures will help to ensure that proper procedures that directly affect data quality are followed. General practices that help to ensure quality include monitoring the functionality of all instruments on a daily basis, ensuring that the full site was surveyed and ensuring that there are no data gaps. Finally, qualification of geophysical operators is critical to ensuring that those operating the equipment can repeat the anticipated performance of the detection system. Chapter 8 describes qualification of geophysical operators in more detail.

4.3 Emerging UXO Detection Systems

The detection systems discussed in the following sections are in various stages of development and implementation. Some are still being researched and tested, while others will be available for operational use in the near future. All of the systems discussed are advanced versions of EMI and magnetometry technologies. The EMI systems discussed below collect vast quantities of data at each position that is used for identification and discrimination purposes, while the magnetometry systems are modifications to accommodate additional operational platforms.

4.3.1 Advanced EMI Systems

There is a whole class of advanced EMI systems in research and development at DoD.

GEM-3 (Geophex Ltd.) — The Geophex Ltd. GEM-3 is a multichannel frequency-domain EMI system that collects the EMI data over many audio frequencies. In other words, the GEM-3 collects multiple channels of information at each survey point. Frequency response data are used for the discrimination of UXO targets from clutter (both manmade and natural). This system has performed well in field tests for discrimination and identification of UXO.

EM-63 (Geonics Ltd.) — The EM-63 is a time-domain EM sensor that records multiple channels of time-domain data at each survey point. It is already commercially available.[63] Processing approaches to fully exploit the additional data measured by the EM-63 are currently being researched.

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[63]ERDC/EL TR-01-20, Advanced UXO Detection/Discrimination Technology Demonstration, U.S. Army Jefferson Proving Ground, Madison, Indiana, Ernesto Cespedes, September 2001.

NAEVA Geophysics has demonstrated good performance with the EM-63 in field tests. Zonge Engineering has also developed a multitime gate, multiaxis system currently being characterized.

4.3.2 Airborne Detection

Airborne detection platforms have been tested at the Badlands Bombing Range, near Interior, South Dakota. Tests suggest that this platform can be very cost-effective in large expanses of flat, open, and treeless ranges found in the arid and semi-arid climate of the western United States, where aircraft are able to fly close to the ground. Other types of sites where speculation suggests airborne platforms may be appropriate include areas where access is made difficult, such as marshes, swamps, wetlands, and shallow water.

Airborne Magnetometry — Low-altitude airborne magnetometry has proved promising in tests on the Cuny Table at the Badlands Bombing Range, near Interior, South Dakota. Because of the conditions at Badlands Bombing Range, aircraft are able to fly close to the ground, providing for increased detection capabilities. Originally, the mission envisioned for airborne magnetics was the identification of the concentrations of munitions for further investigation by ground-based sensors. However, performance in initial tests of commercial, off-the-shelf equipment indicated that for large ordnance (210 kg), individual items were detectable at about 50 percent of the rate of ground-based sensors. Research to improve the probability of detection is ongoing. Aircraft-mounted magnetometers may present a viable option for detecting and characterizing UXO at certain ranges, because the relatively low operation time required to characterize a very large range makes the detection time and cost per acre potentially reasonable despite the high setup and equipment costs.[64]

Airborne MTADS — A second major type of airborne detection is the Airborne MTADS, an adapted version of the vehicular MTADS magnetometry technology for deployment on an airborne platform. The array consists of seven full-field cesium vapor magnetometers (a variant of the Geometrics 822 sensor designated as Model 822A) mounted on a model 206L Bell range helicopter. All sensors are interfaced to a data acquisition computer.

The intent of the adaptation was to provide a MEC site characterization capability for extended, large areas that are inappropriate for vehicular surveys. Because the sensors are deployed further from the ground surface than the vehicular systems, it was understood that some detection sensitivity would be lost. The primary goal of the development was to retain as much detection sensitivity as possible for individual MEC targets. The second primary objective was that the final system must have a production rate and costs appropriate for deployment to explore very large sites that would be prohibitively expensive to survey by other techniques.

[64] *Evaluation of Footprint Reduction Methodology at the Cuny Table in the Former Badlands Bombing Range*, Environmental Security Technology Certification Program, July 2000.

Defense Science Board Recommendations, December 2003

In December 2003 the DoD Defense Science Board released the report of its Task Force on Unexploded Ordnance (UXO). One recommendation was for a national assessment of 10 million acres of former ranges contaminated with UXO. The purpose of the assessment to reduce the footprint of the 10 million acres for which the presence of UXO is uncertain to as few as 2 million acres where cleanup should be focused. The assessment would use of low-flying airborne platforms for sensors in appropriate circumstances.

"The Task force sees this approach as most useful for initial, large scale, wide area assessments of UXO sites to determine in a quick survey fashion where there are metallic objects in the ground and where there are not. We do not see it as the final instrument in the UXO detection discrimination process."

Although the recommendation is an interesting idea, the reader should keep in mind the following :

- The effective use of any detection system to reduce the footprint of the range is limited by our knowledge of what was done at the site, and what we are looking for. In other words, a good conceptual site model is essential.
- Effective use of airborne systems platforms currently occurs under specific conditions:
  - The airborne system is able to be deployed fairly close to the ground (e.g., relatively flat terrains).
  - Such platforms are most useful for detecting larger munitions items.
  - With current technologies false alarms are likely to continue to be a problem.

Demonstrations of airborne MTADS at Badlands Bombing Range, near Interior, South Dakota, indicate that the system generates high production rates while maintaining reasonable costs when characterizing very large, open areas. Production rates of 300-400 acres/day were demonstrated with airborne MTADS as compared with 18-24 acres/day with vehicular MTADS. This indicates that the airborne MTADS, rates can be 15 times greater than the vehicular system's. It is expected that the cost per acre is three to five times less with airborne MTADS than with a vehicular array. These rates have yet to be tested. As expected, the demonstrations indicated that a major disadvantage associated with the use of airborne MTADS is the system's inability to detect small classes of UXO buried at significant depth. In addition, using airborne MTADS doesn't prove to be as cost-effective on smaller areas compared with vehicular MTADS because of the deployment costs associated with the airborne platform.[65]

Airborne EM — Airborne electromagnetic induction is under research and development for use at ranges with characteristics similar to those discussed above (e.g., vast, open, treeless, and flat areas). However, unlike airborne magnetometry, airborne EMI could be used at sites with ferrous soils. Because EM signals fall off more quickly with increased distances, the challenge of using this technique from an airborne platform will be greater. Initial tests have shown detectability of large items on seeded sites.

Ground Penetrating Radar Identification — Studies of various GPR systems have been conducted. One study, by Ohio State University with the U.S. Army Corps of Engineers Research and Development Center and the Cold Regions Research and Engineering Laboratory, examined the

[65]J.R. McDonald, D. Wright, N. Khadr, AETC Inc., and H.H. Nelson, Chemical Dynamics and Diagnostics Branch, Naval Research Laboratory. *Airborne MTADS Demonstration on the Impact Area of the Badlands Bombing Range*, September 2001.

capabilities of an ultra-wideband, fully polarimetric GPR system to provide information about the size and shape of buried objects. This study was based on UXO with known target locations, and focused on both detecting the UXO items and classifying specific ordnance types.[66]

4.4 Use of Processing and Modeling To Discriminate UXO

The development of advanced processing and modeling to reduce the false alarm rates, even as ordnance detection performance improves, is evolving. Rather than using a simple amplitude of response in raw physical data exclusively, advanced processing methods organize large quantities of data. In efforts to encourage the development of algorithms for target discrimination without the expense and burden of field data collection, they have made standard sensor data sets for both controlled and live sites publicly available. One example of a sensor data set is EM data in the time-frequency or spatial domain to discriminate particular objects of interest. Statistical methods can be used to associate field geophysical data with signatures of ordnance items that have either been measured or calculated using EM modeling tools. Alternatively, good data can be used to calculate the essential parameters of the targets, such as size, shape, and depth, which can be used to infer the nature of the item giving rise to the return.

> **About Signatures**
>
> The various methodologies deployed to detect UXO produce digital data that is recorded at each survey location. These data are displayed as graphs, charts, and maps that indicate the presence of an anomalous measurement. The graphical reports produce patterns that may be used to estimate the sizes, types, and orientations of UXO. These patterns are called "signatures." Signatures are being used in emerging technologies and rely on databases of electronic signatures to help discriminate between types of UXO, fragments of UXO, naturally occurring metals, and non-MEC scrap.

Aided or automatic target recognition, or ATR, is a term used to describe a hardware/ software system that receives sensor data as input and provides target classes, probabilities, and locations in the sensor data as output. ATR is used to design algorithms to improve detection and classification of targets and assist in discriminating system responses from clutter and other noise signals, thereby reducing the false alarm rate.[67] These techniques are under development and are not yet available for use in the field.

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[66]M. Higgins, C.C. Chen, and K. O'Neill, U.S. Army Corps of Engineers Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory. ESTCP Project 199902 – *Tyndall AFB Site Demo: Data Processing Results for UXO Classification Using UWB Full-Polarization GPR System*, 1999.

[67]Notes from the Aided Target Recognition Workshop, Unexploded Ordnance Center for Excellence, January 28-29, 1998.

AETC, Inc., and Geophex Ltd., under contract to SERDP, have developed a database of GEM-3 electromagnetic induction data to support identification of UXO and nonordnance items based on their frequency-domain electro-magnetic signature. The signature library for a wide variety of UXO and clutter objects was developed at frequencies between 30 Hz and 30 kHz. The database has been set up to organize and make available results from over 60,000 measurements of different sizes and shapes of UXO and non-UXO objects.[68] In addition, software has been developed to analyze the data and identify a wide variety of anomalies.[69]

SERDP and ESTCP

The Department of Defense (DoD) operates two programs designed to develop and move innovative technologies into the field to address DoD's environmental concerns. **SERDP** is DoD's **Strategic Environmental Research and Development Program**. Executed in partnership with both the Department of Energy and EPA, SERDP is designed to identify, develop, and transition technologies that support the defense mission. The second program is the **Environmental Security Technology Certification Program (ESTCP)**. The goal of the ESTCP is to demonstrate and validate promising innovative technologies. Both organizations have made heavy investments in detection, discrimination, and cleanup technologies for UXO.

The Naval Research Laboratory has developed a technique that uses data fusion to discriminate objects detected in magnetometry and electromagnetic surveys. The laboratory has developed model-based quantitative routines to identify the target's position, depth, shape, and orientation (see Fact Sheet 2 for a full description of MTADS). In addition, location information, including position, size, and depth, is expected to be improved to a small degree.[70] This data fusion method is primarily effective in the discrimination of large MEC items. However, the major contribution of this system and the AETC/Geophex system described above is anticipated to be their ability to differentiate MEC from fragments of ordnance and other clutter.

DoD is funding multiple universities for advanced processing research. Duke University, for example, has engaged in both physics-based modeling and statistical signal processing and has shown performance improvements in many diverse data sets, including EMI, magnetometer, and GPR/SAR.

4.5 MEC Detection Demonstration Programs

Several demonstration programs have been developed to test the effectiveness of various UXO detection sensors and systems in controlled environments. Because of the lack of technologies available to effectively locate UXO on thousands of acres of DoD ranges being closed or realigned under the BRAC program, Congress established the Jefferson Proving Ground Technology Demonstration Program. Since then, other programs such as the former Fort Ord Detection and Discrimination Study and the Environmental Security Technology Certification Program (ESTCP) UXO Technology Standardized Demonstration Sites have been established to further the development of UXO detection technologies.

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[68]EMI signature database in Microsoft Access available at FTP host: server.hgl.com, log in ID: anonymous, File:/pub/SERDP/GEM3.data.zip.

[69]T. Bell, J. Miller, D. Keiswetter, B. Barrow, I.J. Won. *Processing Techniques for Discrimination Between Buried UXO and Clutter Using Multisensor Array Data*, Partners in Environmental Technology Conference, December 2, 1999.

[70]J.R. McDonald. *Model-Based Data Fusion and Discrimination of UXO in Magnetometry and EM Surveys*, Naval Research Laboratory, May 18, 1999.

4.5.1 Jefferson Proving Ground Technology Demonstration Program

Congress established the JPGTD program in response to the realization that the BRAC process could not take place until thousands of acres of military property littered with UXO were cleaned up. Available technologies were also inefficient and inadequate to address the widespread need to detect and remove UXO on such a large scale. (See Chapter 7; "Mag and Flag" had been in use for several decades with few advances or improvements.)

The JPGTD program was established under the management of the U.S. Army Environmental Center (USAEC) to identify innovative technologies that would provide more effective, economical, and safe methods for detecting and removing munitions from former DoD testing and training areas. The program also was created to examine the capability of commercial and military equipment to detect, classify, and remove UXO and to develop baseline performance standards for UXO systems. The JPGTD program aimed to (1) establish criteria and metrics to provide a framework for understanding and assessing UXO technology, (2) provide funding for technology demonstrations, (3) document the performance of advanced technologies to give decision makers a better understanding of the capabilities and limitations of the technologies; and (4) improve demonstration methodologies so that the results would be applicable to actual UXO clearance operations and decision making. The objectives and results of each of the demonstration projects are outlined in the next text box.

UXO detection technologies such as magnetometry, electromagnetic induction, ground penetrating radar, and Multisensor systems were tested and analyzed using a variety of platforms and data processing systems at the JPGTD. The platforms analyzed for the detection technologies included airborne, man-portable, vehicle-towed, and combination man-portable and vehicle-towed. Systems were analyzed using evaluation criteria such as probability of detection, false alarm rate, and other parameters, as described in the adjacent text box. Certain local and regional conditions and soil characteristics (e.g., soil type, moisture, resistivity) may impact the effectiveness of detection systems. Specifically, detector performance may differ significantly at sites with conditions different from those at Jefferson Proving Ground (e.g., ranges in the western U.S. with different soil resistivity/conductivity).

Demonstrator Evaluation Criteria

- Detection capability
- False negative rate
- False positive rate
- Target position and accuracy
- Target classification capability
- Survey rate (used in Phase I only)
- Survey costs (used in Phase I only)

Each of the four phases of JPGTD provided useful data about UXO detection and remediation technologies. In Phase I, conducted in 1994, 26 demonstrators, representing magnetometry, electromagnetic induction (EMI), ground penetrating radar (GPR), synthetic aperture radar (SAR), and infrared (IR) sensors, performed using 20 vehicle-mounted and man-towed platforms and six airborne platforms. Only one demonstrator achieved over a 50 percent detection rate and the false alarm rate was high, an especially disappointing rate considering most of the clutter had been removed prior to the demonstration. Electromagnetic induction, magnetometry, and Gradiometer proved to be the most effective sensors, while GPR, IR, and other imaging technologies were not effective. Airborne systems performed the worst of all the platforms, detecting less than 8 percent of buried ordnance, while hand-held systems had the best performance. At the conclusion of Phase I it was suggested that the geological conditions at the Jefferson Proving Ground may reduce the capabilities of certain sensors.

Therefore, live test sites at five other installations were used to compare the detection data obtained in different geological conditions. Results from the live test sites showed that magnetometry and EMI continued to be the best performers. The average probability of detection at the live test sites was 0.44, and there was a continued inability to distinguish between ordnance and nonordnance.

In Phase II, conducted in 1995, demonstrators had better detection performance, with some sensors detecting over 80 percent of buried ordnance. However, the false alarm rates increased as overall anomaly detection increased. The best performing sensors in Phase II were Multisensor systems combining EMI and magnetometry.

In Phase III, conducted in 1996, four different range scenarios were used to facilitate the development of performance data for technologies used in specific site conditions. Over 40 percent of demonstrators had greater than 85 percent detection, and combination magnetometry and EMI systems repeatedly detected close to 100 percent of buried ordnance. In addition, the Multisensor system, which consisted of electromagnetic induction and either magnetometry or Gradiometer, had a slightly lower than average false alarm rate. However, no sensor or combination of sensors demonstrated an ability to distinguish baseline ordnance from nonordnance, and no system performed better than chance in this area.

Phase IV, conducted in 1998, was aimed at improving the ability to distinguish ordnance and nonordnance. Fifty percent of the demonstrators showed a better than chance probability of discriminating UXO from clutter, with one demonstrator correctly identifying 75 percent of ordnance and nonordnance items. While advanced data processing has greatly improved target discrimination capabilities in pilot testing, these methods need to be further developed and tested. In order to make advanced processing techniques widely used and to develop a market for constantly improving systems, they need to be made commercially available. With reliable and readily available target discrimination technologies, false alarm rates could be greatly reduced, thereby significantly improving the efficiency and reducing the costs of UXO detection and remediation.

Synopsis of Objectives and Results of Jefferson Proving Ground Technology Demonstration Program, Phases I through IV

Phase I, 1994
Objective: Evaluate existing and promising technologies for detecting and remediating UXO.
Results: Limited detection and localization capabilities and inability to discriminate between ordnance and nonordnance. Average false alarm rate was 149 per hectare. Airborne platforms and ground penetrating radar sensors performed poorly; combination electromagnetic induction and magnetometry sensors were the best performers, but also had modest probabilities of detection and very high false alarm rates.

Phase II, 1995
Objective: Evaluate technologies effective for detecting, identifying, and remediating UXO, and measuring these results against the Phase I baseline.
Results: Significant improvement in detection capabilities with commensurate increases in false alarms among better performing technologies. Continued inability to distinguish ordnance from nonordnance. Again, airborne platforms and ground penetrating radar sensors performed poorly; combination electromagnetic induction and magnetometry sensors were the better performers, but continued to have very high false alarm rates.

Phase III, 1996
Objective: Develop relevant performance data of technologies used in site-specific situations to search, detect, characterize, and excavate UXO. Four different range scenarios were used, which had typical groups of UXO.
Results: Improvement in detection, but continued inability to distinguish ordnance from nonordnance. Localization performance for ground-based systems improved. Probability of detection is partially dependent on target size. False alarm rates ranged from 2 to 241 per hectare.

Phase IV, 1998
Objectives: Demonstrate the capabilities of technology to discriminate between UXO and non-UXO; establish discrimination performance baselines for sensors and systems; make raw sensor data available to the public; establish state of the art for predicting ordnance "type"; direct future R&D efforts.
Results: Capability to distinguish between ordnance and nonordnance is developing. Five demonstrators showed a better than chance probability of successful discrimination.

4.5.2 Former Fort Ord Ordnance Detection and Discrimination Study (ODDS)

A phased geophysical study of ordnance detection and discrimination specific to the former Fort Ord, California, environment has been in existence since 1994. In November 1998, the U.S. Army evaluated MEC at Fort Ord in an "Ordnance and Explosives Remedial Investigation/Feasibility Study (OE RI/FS)" concurrently with removal actions. The RI/FS evaluated long-term response alternatives for cleanup and risk management at Fort Ord. The technologies considered for use during the Fort Ord study were demonstrated during the Jefferson Proving Ground study. The following text box describes the four phases of the Fort Ord study.

Synopsis of Objectives and Results of the Former Fort Ord Ordnance Detection and Discrimination Study (ODDS), Phases I through IV

Phase I
Objective: Evaluate detection technologies "Static" measurements in free air (i.e., in the air above and away from ground influences/effects) given variable ordnance items, depths, and orientations.
Results: Signal drop-off in the electromagnetic (EM) response is proportional to the depth of the object to the 6^{th} power. For horizontally oriented ordnance items, the EM signal response was predicted fairly well.

Phase II
Objective: Evaluate the effectiveness of geophysical instruments' ability to detect and locate "seeded" or planted ordnance items.
Result: Noise levels increased 3 to 35 times from the static to seeded tests. There was a significant degradation of profile signatures between static and field trial tests.

Phase III
Objective: Evaluate geophysical instruments and survey processes at actual uninvestigated munitions response sites.
Results: The effects of rough terrain and vegetation on detection and discrimination capabilities can be significant. Removal of range residue before the munitions response investigation began would have reduced time and effort spent on unnecessary excavations.

Phase IV
Objective: Evaluate discrimination capabilities of ordnance detection systems.
Results: The instruments with the highest detection rate required the most intrusive investigation. Conversely, instruments with lower detection rates required less intrusive investigations. **The ODDS determined that no one instrument provides the single solution to meet the ordnance detection needs at Fort Ord.**

The first phase of the ODDS found the electromagnetic and magnetometer systems to be effective in the detection and location of buried MEC items. Phase II was conducted in a controlled testing environment. The controlled area consisted of five "seeded" plots. Two of the plots consisted of items with known depths and orientations, while the other three areas consisted of "unknown" plots where target information was withheld. The plots were designed to be representative of the terrain of Fort Ord. The seeded tests concluded that the noise levels of the EMI systems increased 3 to 35 times from the static to seeded tests. In Phase III it was concluded that the effects of terrain, vegetation, and range residues can significantly alter detection and discrimination capabilities of the detectors. Phase IV of the study determined that discrimination capability of the instruments tested was minimal. The Phase IV study also determined that both EMI and magnetometer systems performed well in finding the larger and deeper items, whereas only the EMI systems consistently found smaller and shallower items. The results indicated that different systems are required for different types of sites, depending on the MEC expected and the site-specific environmental and geological conditions.

4.5.3 UXO Technology Standardized Demonstration Sites

The U.S. Army Environmental Center (USAEC) is conducting an ESTCP-funded program to provide UXO technology developers with test sites for the evaluation of UXO detection and discrimination technologies using standardized protocols. The USAEC is developing standardized test methodologies, procedures, and facilities to help ensure accuracy and replicability in measurements of detection capability, false alarms, discrimination, target reacquisition, and system efficiency. Data generated from these standardized sites will be compiled into a technology-screening matrix to assist UXO project managers in selecting the appropriate detection systems for their application.

Standardized test sites will be made up of three areas – the calibration lane, the blind grid, and the open field. The calibration area will contain targets from a standardized target list at six primary orientations and at three depths. The target depth, orientation, type, and location will be provided to demonstrators. The calibration area will allow demonstrators to test their equipment, build a site library, document signal strength, and deal with site-specific variables. In the blind grid area, demonstrators will know possible locations of targets and will be required to report whether or not a UXO target clutter or nothing actually exists there. If a UXO target is found, they must report the type of target, classification of target, and target depth and a confidence level. The blind grid allows testing of sensors without ambiguities introduced by the system, site coverage, or other operational concerns. The open field will be a 10 or more acre area with clutter and geolocation targets about which demonstrators will be given no information and will be required to perform as if they were performing at an actual DoD range. Testers will report the location of all anomalies, classify them as clutter or UXO, and provide type, classification, and depth information. The open field conditions will document the performance of the system in an actual range operation mode.

In addition to the construction of test sites available to the UXO community, the primary products of this program will be the creation of a series of protocols to establish procedures necessary for constructing and operating a standardized UXO test site. A standardized target repository will be amassed that can be used by installations, technology developers, and demonstrators.

4.6 Fact Sheets and Case Studies on Detection Technologies and Systems

Three fact sheets on MEC sensors and three case studies describing detection systems are found at the end of this chapter as Attachments 1 through 6. Information on the nature of the technology and its benefits and limitations is provided. Since the performance of the instruments is not solely based upon the sensors deployed, the case studies provide more insights on the operation of the systems. The performance of detection systems is dependent upon platform characteristics, survey methodology and quality, data processing, personnel operation/performance, site characterization, and appropriate quality control measures that should be taken throughout the investigation.

4.7 Conclusion

The performance of many existing and emerging technologies for MEC detection and discrimination is limited by specific site characteristics such as soil type and composition, topography, terrain, and type and extent of contamination. What works at one site may not work at another. Our ability to find MEC in subsurface locations has improved dramatically. The JPGTD studies have shown that we have gotten much smarter about how to deploy these technologies and how to locate a high percentage of UXO. However, the results of a controlled study such as the JPGTD should not give us unrealistic expectations about the capabilities of these technologies when used in range investigation. Studies at true MEC areas, such as at Fort Ord, provide additional information about the challenges and issues that have to be considered in selecting MEC detection systems. For example, the nature of the targets (e.g., composition, size, and mass), the depth of MEC penetration (a function of the soil and the ordnance item), and expected spatial and depth distribution should be considered along with the geology, terrain, and vegetation. Other factors affecting the results include operator performance and postprocessing techniques. Given the sizes of the ranges and the cost of investigating anomalies, the greatest challenge to improving MEC detection is being able to discriminate MEC from other subsurface anomalies. Although there have been improvements in this area, much developmental work remains.

ATTACHMENT 4-1. FACT SHEET #1: MAGNETOMETRY

FACT SHEET #1: MEC DETECTION TECHNOLOGIES	**Magnetometry**
What is magnetometry?	Magnetometry is the science of measurement and interpretation of magnetic fields. Magnetometry, which involves the use of **magnetometers** and **gradiometers**, locates buried ordnance by detecting irregularities in the Earth's magnetic field caused by the ferromagnetic materials in the ordnance assembly. The magnetometer can sense only *ferrous materials*, such as iron and steel; other metals, such as copper, tin, aluminum, and brass, are not ferromagnetic and cannot be located with a magnetometer. Although they have been in use for many years and many newer technologies are available, magnetometers are still considered one of the most effective technologies for detecting subsurface MEC and other ferromagnetic objects. Magnetometry remains the most widely used subsurface detection system today. The two basic categories of magnetometer are total-field and vector. C The **total-field magnetometer** is a device that measures the magnitude of the magnetic field without regard to the orientation of the field. C The **vector magnetometer** is a device that measures the projection of the magnetic field in a particular direction. A **magnetic gradiometer** is a device that measures the spatial rate of change of the magnetic field. Gradiometers generally consist of two magnetometers configured to measure the spatial rate of change in the Earth's magnetic field. The gradiometer configuration was designed to overcome large-scale diurnal intensity changes in the Earth's magnetic field; this design may also be used to minimize the lateral effects of nearby fences, buildings, and geologic features.
How are magnetometers used to detect MEC?	Magnetometers can theoretically detect every MEC target that contains ferrous material, from small, shallow-buried MEC to large, deep-buried MEC, provided that the magnetic signature is larger than the background noise. A magnetometer detects a perturbation in the geomagnetic field caused by an object that contains ferrous material. The **size**, **depth**, **orientation**, **magnetic moment**, and **shape** of the target, along with **local noise fields** (including ferrous clutter), must all be considered when assessing the response of the magnetometer.

FACT SHEET #1: MEC DETECTION TECHNOLOGIES

Magnetometry

What are the different types of magnetometers?

There are numerous types of magnetometers, which were developed to improve detection sensitivity. Three of the most common are the **cesium vapor**, **proton precession**, and **fluxgate** magnetometers.

- **Cesium vapor magnetometers –** These magnetometers are lightweight and portable. The sensor can also be mounted on a nonmagnetic platform. The principal advantage of this type of magnetometer is its rapid data collection capability. The common hand-held sensors are capable of measuring at a rate of 10 times per second, and specially designed sensors are capable of measuring at a rate of 50 times per second. The one disadvantage of this magnetometer is that it is insensitive to the magnetic field in certain directions, and dropouts can occur where the magnetic field is not measured. However, this can be avoided with proper field procedures.
- **Proton precession magnetometers –** These magnetometers have been used in clearing Munitions Response Sites (MRS), but achieving the data density required for a MRS is time consuming. The primary disadvantage of these types of magnetometers is that accurate measurements require stationary positioning of the sensor for a period of several seconds. Also, these magnetometers require tuning of the local magnetic field. *The primary use of these magnetometers today is as a base station for monitoring diurnal variations in the Earth's magnetic field and possible geomagnetic storms*.
- **Fluxgate magnetometers –** These magnetometers are used primarily to sweep areas to be surveyed. They are also used in locating MEC items during reacquisition. These magnetometers are relatively inexpensive, locate magnetic objects rapidly, and are relatively easy to operate. The disadvantage of these types of magnetometers is that most of them do not digitally record the data, and accurate measurements require leveling of the instrument.

What are the components of a magnetometer?

A passive magnetometer system includes the following components:

- **The detection sensor**
- **A power supply**
- **A computer data system**
- **A means to record locations of detected anomalies**

More technologically advanced systems typically incorporate a navigation system, such as a differential global positioning system (DGPS), to determine locations. Advanced navigation systems may also include a graphical output device (printer), a mass data storage recorder, and telecom systems.

FACT SHEET #1: MEC DETECTION TECHNOLOGIES

Magnetometry

What are the operational platforms for a magnetometer?

Magnetometers can be transported in a variety of ways:

- **Man-portable**
- **Towed by a vehicle**
- **Airborne platforms**

Magnetometers are most frequently used on man-portable platform, but they also can perform well when towed on a vehicular platforms, as long as the vehicular platform and sensor array have been carefully designed to minimize magnetic noise and ensure high quality data collection. These platforms are restricted to areas accessible to vehicles. Airborne systems are currently being evaluated for commercial use as discussed in **Section 4.3.**

Figure 4-1. Hand-Held Magnetometer

One of the most commonly used and oldest UXO detection methods is the **"Mag and Flag"** process. Mag and Flag involves the use of hand-held magnetometers by MEC technicians, who slowly walk across a survey area and flag those areas where MEC may be located for later excavation. The success of the method is dependent on the competence and alertness of the technician and his ability to identify changes in the audible or visible signals from the magnetometer indicating the presence of an anomaly.

What are the benefits of using magnetometry for detecting MEC?

The **benefits** of using magnetometry for MEC detection include the following:

- Magnetometry is considered one of the *most effective technologies* for detecting subsurface MEC and other ferromagnetic objects.
- Magnetometry is one of the *more developed technologies* for detection of MEC.
- Magnetometers are fairly *simple devices*.
- Magnetometers are *nonintrusive*.
- Relative to other detection technologies, magnetometers have *low data acquisition costs.*
- Magnetometers have the ability to *detect ferrous items to a greater depth* than can be achieved using other methods.
- Depending on the data acquisition and post processing systems used magnetometers *can provide fair to good information on the size of the detected object*.
- Because magnetometers have been in use since World War II, the *limitations are well understood*.

FACT SHEET #1: MEC DETECTION TECHNOLOGIES	**Magnetometry**
What are the limitations of using magnetometry for detecting MEC?	The **limitations** of using magnetometry for MEC detection include the following: C The effectiveness of a magnetometer can be reduced or inhibited by interference (noise) from *magnetic minerals or other ferrous objects in the soil*, such as rocks, pipes, drums, tools, fences, buildings, and vehicles, as well as MEC debris. C Depending on the data analysis systems used, magnetometers may suffer from *high false alarm rates*, which lead to *expensive excavation efforts.* C Depending on the site conditions, *vegetation and terrain may limit the ability to place magnetometers* (especially vehicle-mounted systems) near the ground surface, which is needed for maximum effectiveness. C Magnetometers have *limited capability to distinguish targets that are located near each other*. Clusters of ordnance of smaller size may be identified as clutter, and distributed shallow sources (MEC or not) may appear as localized deep targets. Accurately distinguishing between targets depends heavily on coordination between sensors, navigation, and processing.

FACT SHEET #2: MEC DETECTION TECHNOLOGIES	**Electromagnetic Induction (EMI)**
What is electromagnetic induction (EMI) and how is it used to detect MEC?	**Electromagnetic induction** is a geophysical technology used to induce a magnetic field beneath the Earth's surface, which in turn causes a secondary magnetic field to form around nearby objects that have conductive properties. The secondary magnetic field is then measured and used to detect buried objects. *Electromagnetic induction systems are used to detect both ferrous and nonferrous MEC.* In electromagnetic induction, a primary transmitter coil creates a time-dependent electromagnetic field that induces eddy currents in the subsurface. The intensity of the currents is a function of ground conductivity and the possible presence of metallic objects in the subsurface. The secondary, or induced, electromagnetic field caused by the eddy currents is measured by a receiver coil. The voltage measured in the receiver coil is related to the physical properties of the subsurface conductor. The strength and duration of the induced field depend on the size, shape, conductivity, and orientation of the object. There are two basic types of EMI methods: frequency domain and time domain. C **Frequency-domain EMI** measures the response of the subsurface as a fraction of frequency. Generally, a receiver coil shielded from the transmitted field is used to measure the response of targets. Frequency-domain sensors, such as the mono-static, multi-frequency **Geophex GEM-3**, are used for MEC detection. In addition, the Geonics EM31 has been used for detecting boundaries of trenches that may be MEC disposal sites. C **Time-domain EMI** measures the response of the subsurface to a pulsed electromagnetic field. After the transmitted pulse is turned off, the receiving coil measures the signal generated by the decay of the eddy currents in any nearby conductor. These measurements can be made at single time gates, which may be selected to maximize the signal of targets sought. In more advanced instruments, measurements can be made in several time gates, which will increase the information obtained about the physical properties of the targets. The time-domain EMI sensor that is commonly used for MEC detection is the **Geonics EM-61**. Under ideal conditions, the **EM-61** instrument is capable of detecting large UXO items at depths of as much as 10 feet below ground surface when ground clutter from debris does not exceed the signal level. The instrument can detect small objects, such as a 20 mm projectile, to depths of approximately 1 foot below ground surface, if noise (terrain and instrument) conditions are less than the response of the object.
How effective is EMI for detecting MEC?	The effectiveness of EMI systems in detecting MEC depends on many factors, including **distance between sensor and UXO, metallic content of MEC**, **concentrations of surface ordnance fragments**, and **background noise levels**. EMI methods are well suited for reconnaissance of large open areas because data collection is rapid. Vertical resolution is transmitter and target dependent. The range of frequencies for electromagnetic instruments used in MEC site characterization is from approximately 75 Hz (cycles per second) to approximately 1,000 kHz.

FACT SHEET #2: MEC DETECTION TECHNOLOGIES	# Electromagnetic Induction (EMI)
What are the components of an EMI system?	The components of an EMI system include the following: C **Transmitting and receiving units** C **A power supply** C **A computer data acquisition system** C **A means of recording locations of detected metallic anomalies** Advanced systems incorporate a navigation system as well, such as a **differential global positioning system (DGPS)**.
What are the operational platforms for an EMI system?	In general, EMI systems are configured on man-portable units. Such units often consist of the following items: C **A small, wheeled cart used to transport the transmitter and receiver assembly** C **A power supply** C **An electronics backpack** C **A hand-held data recorder**  **Figure 4-2. EM-61 System** In general, EMI systems are configured to be man portable or towed by a vehicle. However, vehicle-towed systems are limited in that the platform can be a source of background noise and interference with target detection and they have high potential for mechanical failures. In addition, vehicle-towed systems can only be used on relatively flat and unvegetated areas. *Man-portable systems provide easier access to areas of a site that are accessible to personnel. In general, man-portable systems are the most durable and require the least maintenance.*
What are the benefits of using EMI for detecting MEC?	The **benefits** of using EMI include the following: C EMI can be used for *detecting all metallic objects near the surface of the soil*, not only ferrous objects. C EMI has potential to *discriminate clusters of MEC from a single item*. C EMI sensors *permit some measure of control over their response to ordnance and other metal objects*. C EMI systems are generally *easy to use*. C EMI is *nonintrusive*. C Man-portable EMI systems *provide access to all areas of a site, including uneven and forested terrain*.

FACT SHEET #2: MEC DETECTION TECHNOLOGIES	**Electromagnetic Induction (EMI)**
What are the limitations of using EMI for detecting MEC?	The **limitations** of using EMI to detect MEC include the following: C Depending on the data acquisition and processing systems used EMI may suffer from fairly *large false alarm rates*, particularly in areas with high concentrations of surface ordnance fragments. (Some buried metallic debris can produce EMI signatures that look similar to signatures obtained from MEC, which results in a large false alarm rate.) Specifically, EMI sensors that utilize traditional detection algorithms based solely on the signal magnitude suffer from high false alarm rates as well. C Implementing EMI systems in areas on the range that may contain electronically fuzed ordnance could be *unsafe because the induced magnetic field could detonate the ordnance.* (However, this is very unlikely because the EMI power density and induced current is very low in most systems.) C *Large metal objects can cause interference*, typically when EMI is applied within 5 to 20 feet of power lines, radio transmitters, fences, vehicles, or buildings.
What are the costs of using EMI to detect MEC?	Per acre costs for EMI vary depending on the operational platform, the terrain, and other factors.

FACT SHEET #3: MEC DETECTION TECHNOLOGIES	**Ground Penetrating Radar (GPR)**
What is GPR?	**Ground penetrating radar (GPR)**, sometimes called ground probing radar, georadar, or earth sounding radar, is a well-established remote sensing technology that can detect metallic and nonmetallic objects. Only recently (within the last 10 years) has GPR been applied to locating and identifying MEC at military sites on a limited basis. *Under optimum conditions, GPR can be used to detect individual buried munitions up to 5 feet below the ground surface. However, such optimum conditions seldom occur and the method has not been extremely successful in detecting UXO.* GPR is not routinely used to perform detection of individual UXO, but may be useful for detecting large masses of buried ordnance.
How is GPR used to detect MEC?	**GPR** uses high-frequency electromagnetic waves (i.e., radar) to acquire subsurface information. Both time-domain (impulse) and stepped frequency GPR systems are in use today. C **Time-domain (pulsed)** sensors transmit a pulsed frequency. The transmitter uses a half-duty cycle, with the transmitter on and off for equal periods. C **Stepped frequency domain** sensors transmit a continuous sinusoidal electromagnetic wave. The waves are radiated into the subsurface by an emitting antenna. As the transmitted signal travels through the subsurface, "targets," such as buried munitions or stratigraphic changes, reflect some the energy back to a receiving antenna. The reflected signal is then recorded and processed. The travel time can be used to determine the depth of the target. GPR can potentially be used to verify the **emplacement**, **location**, and **continuity** of a subsurface barrier. The GPR method uses antennas that emit a single frequency between 10 MHz and 3,000 MHz. *Higher frequencies provide better subsurface resolution at the expense of depth of penetration. Lower frequencies allow for greater penetration depths but sacrifice subsurface target resolution.* In addition to the radar frequency, the depth of wave penetration is controlled by the electrical properties of the media being investigated. *In general, the higher the conductivity of the media, the more the radar wave is attenuated (absorbed), lessening the return wave.* Electrically conductive materials (e.g., many mineral clays and moist soil rich in salts and other free ions) rapidly attenuate the radar signal and can significantly limit the usefulness of GPR. In contrast, in dry materials that have electrical conductivity values of only a few millimhos per meter, such as clay-free soil and sand and gravel, penetration depths can be significantly greater. Penetration depths typically range between 1 and 5 feet. In addition, subsurface inhomogeneity can cause dispersion, which also degrades the performance of radars. *As a result, it is important to research the subsurface geology in an area before deciding to use this method.* GPR measurements are usually made along parallel lines that traverse the area of interest. The spacing of the lines depends on the level of detail sought and the size of the target(s) of interest. The data can be recorded for processing off-site, or they can be produced in real time for analysis in the field.

FACT SHEET #3: MEC DETECTION TECHNOLOGIES	**Ground Penetrating Radar (GPR)**
What are the components of a GPR system?	The components of a GPR systems consist of the following: C **A transmitter/receiver unit** C **A power supply** C **An antenna** C **A control unit** C **A display and recorder unit** C **Geolocation ability** GPR systems are available for commercial use. *The pulsed systems are the most commonly used and are available from a variety of vendors.* Physically commercial systems provide a selection of antennas that operate at frequency bandwidths. Antennas are available from the gigahertz range for extremely shallow targets to the megahertz range for greater depths of ground penetration.
What are the benefits of using GPR for detecting MEC?	The **benefits** of using GPR to detect MEC are as follows: C GPR is *nonintrusive*. C GPR is *potentially able to identify breach and discontinuity and determine the size of both*. C GPR *may provide a three-dimensional image of the structure*. (Requires very sophisticated processing and data collection.) C GPR can help define boundaries, if you know the location of buried munitions. C *Under optimum conditions, GPR may be used to detect individual buried munitions several meters deep*. In areas with **dry soils and sparse vegetation**, GPR systems may produce accurate images as long as the antenna is positioned perpendicularly to the ground.
What are the limitations of using GPR for detecting MEC?	The **limitations** of using GPR to detect UXO include the following: C *The primary limitation of the GPR system is that its success is site specific and not reliable*. Low-conductivity soils are necessary if the method is to penetrate the ground. Soils with high electrical conductivity (e.g., many mineral clays and moist soil rich in salts) rapidly attenuate the radar signal, inhibiting the transmission of signals and significantly limiting usefulness. *Even a small amount of clay minerals in the subsurface greatly degrade GPR's effectiveness.* C *Lower frequencies can penetrate to a greater depth, but result in a loss of subsurface resolution*. Higher frequencies provide better subsurface resolution, but at the expense of depth of penetration. C *Interpretation of GPR data is complex*; an experienced data analyst is required. C *High signal attenuation decreases the ability of GPR systems to discriminate UXO* and increases the relative amount of subsurface inhomogeneity (i.e., soil layers, pockets of moisture, and rocks). C *Airborne GPR signals may not even contact the soil surface* because the signals are reflected by the vegetation or are absorbed by water in the vegetation.

Case Study on the Use of a Multisensor System

The **Multisensor system** combines two or more sensor technologies with the objective of improving UXO detection performance. *With multiple-sensor systems operating in a given area, complementary data sets can be collected to confirm the presence of UXO, or one system may detect a characteristic that another system does not.*

The technologies that have proven to be most effective both individually and deployed in Multisensor systems are the **Geonics EM61 electromagnetic detection system** and the **cesium vapor magnetometer**. Other types of sensors have been tested and evaluated, but they are still under development and research continues.

The Naval Research Laboratory's **MTADS** represents a state-of-the-art, automated, MEC detection system. The system incorporates arrays of **full-field cesium vapor magnetometers** and **time-domain EMI pulsed sensors**. The sensors are mounted as linear arrays on low-signature platforms that are towed over survey sites by an all-terrain vehicle. The position over ground is plotted using state-of-the-art real-time kinematic Differential global positioning system technology that also provides vehicle guidance during the survey. An integrated **data analysis system** processes MTADS data to locate, identify, and categorize all military ordnance at maximum probable self-burial depths.

During the summer of 1997 the system was used to survey about 150 acres at a bombing target and an aerial gunnery target on the Badlands Bombing Range on the Oglala Sioux Reservation in Pine Ridge, South Dakota. Following the survey and target analysis, UXO contractors and personnel from the U.S. Army Corps of Engineers, Huntsville, selectively remediated targets to evaluate both the detection and discrimination capabilities of MTADS. Two remediation teams worked in parallel with the surveying operations. The full distribution of target sizes was dug on each target range because one goal of the effort was to create a database of both ordnance and ordnance clutter signals for each sensor system that could be used to develop an algorithm for future data analysis.

An initial area of 18.5 acres was chosen as a test/training range. All 89 analyzed targets were uncovered, documented, and remediated. Recovered targets in the training areas included 40 M-38 100-pound practice bombs, four rocket bodies and warheads, and 33 pieces of ordnance scrap (mostly tail fins and casing parts). The smallest intact ordnance items recovered were 2.25-inch SCAR rocket bodies and 2.75-inch aerial rocket warheads. Information from the training area was used to guide remediation on the remainder of both ranges.

Magnetometry and **EM** data analysis identified a total of 1,462 targets on both ranges. Of these, 398 targets were selected for remediation. For each target, an extensive digsheet was filled out by the remediation team to augment the photographic and digital electronic GPS records. Recovered ordnance-related targets included 67 sand-filled M-38 practice bombs, four M-57 250-pound practice bombs, and 50 2.25-inch and 2.75-inch rocket bodies and rocket warheads. In addition, 220 items of ordnance-related scrap were recovered. The target depths were generally predicted to within 20 percent of the actual depths of the target centers.

MTADS has the sensitivity to detect all ordnance at its likely maximum self-burial depths and to locate targets generally within the dimensions of the ordnance. *On the basis of all evaluation criteria, the MTADS demonstration, survey, and remediation were found to be one of the most promising system configurations given appropriate site-specific conditions and appropriately skilled operators.*

Case Study of a Detection System with Magnetometry

In August 1998, Geophysical Technology Limited (GTL) used an eight-sensor magnetometer system towed by an autonomous tow vehicle (ATV) to detect UXO over approximately 200 acres of the flat and treeless Helena Valley in Helena, Montana. The system was navigated by a real-time differential global positioning system (DGPS).

The system had the following main features:

- The trailer used was low cost, and any standard four-wheel bike could be used to tow the array. This means that the system can be easily duplicated, and multiple systems can be run on large or concurrent projects.
- The system had a high-speed traverse, a 4-meter swath, and complete Differential global positioning system coverage, making it very efficient.
- The TM-4 magnetometer at the center of the system was the same instrument used in the hand-held application for surveying fill-in areas inaccessible to the trailer system.

The one-operator trailer system did not require a grid setup prior to the commencement of the surveys. The survey computer guided the operator along the survey lanes with an absolute cross-track accuracy of 0.75 meters (vegetation and terrain permitting). An expandable array of magnetic sensors with adjustable height and separation allowed the operators to optimize the system for this application. Eight sensors, 0.5 meters apart, were used in the survey.

GTL's proprietary MAGSYS program was used for detailed anomaly interpretation and the printing of color images. Magnetic targets that were identified were then modeled using a semiautomatic computer-aided procedure within MAGSYS. A selection of key parameters (position, depth, approximate mass, and magnetic inclination) was used to adjust the model for best fit. The confidence that the interpreted items were UXO was scaled as high, medium, and low according to their least squares fit value. GTL's system successfully detected over 95 percent of the emplaced 76 mm and 81 mm mortar projectiles.

In Montana accurate real-time Differential global positioning system positioning and navigation resulted in good coverage of the survey areas using the trailer system. The GTL trailer system enables practical, fast collection of high-resolution, accurately positioned magnetic data, as required for UXO detection.

The GTL trailer system opens new possibilities of covering large areas efficiently, and it is an important milestone in achieving large-scale remediation with performance that is quantifiable.

Case Study on the Use of Ground Penetrating Radar in a Multisensor Data Acquisition System

GPR is not often used as a stand-alone MEC detection technology because its detection capabilities are limited. GPR is most commonly used as part of a Multisensor system, such as the one described below.

The Air Force Research Laboratory at Tyndall AFB has developed a semiautonomous MEC detection, characterization, and mapping system. The system consists of two major functional components: an unmanned autonomous tow vehicle (ATV) and a Multisensor data acquisition system. By combining an ATV, the GPR's highly accurate positioning and mapping systems, and a multiple-sensor platform, operators plan, execute, and analyze collected data while monitoring the vehicle and data acquisition system at a safe distance from the survey site.

The multiple-sensor platform (MSP) provides a mounting structure for an array of four cesium vapor 3- to 5-nanosecond magnetometers, three Geonics EM61 inductance coils, and an **impulse GPR system**. The GPR is suspended below the platform frame using a pinned hanger. An encoder at the GPR hanger point measures the relative GPR angular displacement from the platform frame. In general, the ATV/MSP GPR transmits a series of 3-to 5 - nanosecond, 100- to 250-volt impulses into the ground at a specific pulse repetition interval. Signals received from objects with electrical properties that vary from the surrounding soil are fed through an adjustable attenuator, to a band pass filter, and finally to track-and-hold circuitry, which digitizes and stores collected data. The system uses a single broad-bandwidth antenna, which covers a frequency range of 20 to 250 MHz.

To date, data collection has been conducted at several sites, one of them being Tyndall AFB. The test site in the 9700 area of Tyndall AFB is composed of a loose sandy top layer approximately 20 cm deep and a packed sandy layer that reaches the water table, which starts at a depth of less than 1 meter. The test site provides a homogeneous background in which inert ordnance items, 60 mm mortar projectiles, 105 mm artillery projectiles, miscellaneous clutter, angle iron, barbed wire, concrete blocks, and steel plates were placed to simulate an active range. Data collected at the Tyndall test site included those from the magnetometer, electromagnetic induction (EMI), and GPR.

Analysis of magnetometer, EMI, and GPR cursory calibration raw data was performed in situ at the mobile command station. Synthetic aperture radar (SAR) processing was used to focus the complex and large bandwidth information inherent in GPR data. In order to perform this focusing of the SAR images, the waveforms generated by the GPR must be accurately registered in the time domain, with an associated registration of position in the spatial domain.

The original purpose of the ATV/MSP was to evaluate various sensor systems. It quickly became clear that its higher purpose was to provide a powerful aid to the process of analysis. The accuracy, repeatability, and completeness of coverage obtained during autonomous surveys cannot be matched using manual operations.

The GPR system tested at Tyndall AFB achieved an approximate false alarm rate of 51 percent. Overall, the measured data from the targets and GPR measurements were somewhat close. Currently, the GPR is unable to distinguish between UXO and non-UXO targets if the length-to-diameter (L/D) ratio is greater than 3. The GPR system also had problems identifying UXO-like items buried at an angle greater than 45 degrees, as well as UXO partially buried in the water table.

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

ESTCP (Environmental Security Technology Certification Program). ***Evaluation of Footprint Reduction Methodology at the Cuny Table in the former Badlands Bombing Range***(2000 ESTCP Project), January 2004.

USACE (U.S. Army Corps of Engineers), Research and Development Center (ERDC). ***Data Processing Results for UXO Classification Using UWB Full-Polarization GRP System***. ESTCP Project 199902, Tyndall AFB Site Demo, 1999.

USACE. ***Geophysical Investigations for Unexploded Ordnance (UXO)***. EM 1110-1-4009, Chapter 7, June 23, 2000.

USACE. ***Former Fort Ord Ordnance Detection and Discrimination Study (ODDS)***. Executive Summary, 2000. [Final Report, January 2002.]

U.S. Army Environmental Center (USAEC). ***Evaluation of Individual Demonstrator Performance at the Unexploded Ordnance Advanced Technology Demonstration Program at Jefferson Proving Ground (Phase I)***. Mar. 1995.

USAEC. ***Unexploded Ordnance Advanced Technology Demonstration Program at Jefferson Proving Ground (Phase II)***. June 1996.

USAEC. ***UXO Technology Demonstration Program at Jefferson Proving Ground, Madison, Indiana, (Phase III)***. Apr. 1997.

U.S. Department of Defense (DoD). ***Unexploded Ordnance (UXO)***. BRAC Environmental Fact Sheet, Spring 1999.

U.S. DoD. ***Evaluation of Unexploded Ordnance Detection and Interrogation Technologies, For Use in Panama: Empire, Balboa West, and Pina Ranges***. Final Report. Feb. 1997.

U.S. DoD. ***Final Report of the Defense Science Board Task Force on Unexploded Ordnance***, December 2003.

Information Sources

Air Force Research Laboratory AFRL/MLQC
104 Research Road, Bldg. 9738
Tyndall AFB, FL 32403-5353
Tel: (850) 283-3725
http://www.afrl.af.mil

Colorado School of Mines
1500 Illinois Street
Golden, CO 80401-1887
Tel: (303) 273-3000
http://www.mines.edu

Department of Defense Explosives Safety Board (DDESB)
2461 Eisenhower Avenue
Alexandria, VA 22331-0600
Fax: (703) 325-6227
http://www.ddesb.pentagon.mil

Environmental Security Technology Certification Program (ESTCP)
901 North Stuart Street, Suite 303
Arlington, VA 22203
Tel: (703) 696-2127
Fax: (703) 696-2114
http://www.estcp.org

Joint UXO Coordination Office (JUXOCO)
10221 Burbeck Road, Suite 430
Fort Belvoir, VA 22060-5806
Tel: (703) 704-1090
http://www.denix.osd.mil/UXOCOE

Naval Explosive Ordnance Disposal Technology Division
(NAVEODTECHDIV)
UXO Countermeasures Department, Code 30U
2008 Stump Neck Road
Indian Head, MD 20640-5070
http://www.ih.navy.mil/

Naval Ordnance Environmental Support Office
Naval Ordnance Safety and Security Activity
23 Strauss Avenue, Bldg. D-323
Indian Head, MD 26040
Tel: (301) 744-4450/6752
http://enviro.nfesc.navy.mil/nepss/oeso.htm

Naval Research Laboratory
Chemistry Division, Code 6110
Washington, DC 20375-5342
Tel: (202) 767-3340
http://chemdiv-www.nrl.navy.mil/6110/index.html

Strategic Environmental Research and Development Program (SERDP)
901 North Stuart Street, Suite 303
Arlington, VA 22203
Tel: (703) 696-2117
http://www.serdp.org

U.S. Army Corps of Engineers
Engineering and Support Center, Huntsville
4820 University Square
Huntsville, AL 35816-1822
Tel: (256) 895-1545
http://www.hnd.usace.army.mil

U.S. Army Corps of Engineers
Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
Tel: (601) 634-3723
http://www.erdc.usace.army.mil

U.S. Army Environmental Center (USAEC)
Aberdeen Proving Ground, MD 21010-5401
Tel: (800) USA-3845
http://www.aec.army.mil

U.S. Army Research Laboratory (ARL)
Attn: AMSRL-CS-EA-PA
2800 Powder Mill Road
Adelphi, MD 20783-1197
Tel: (301) 394-2952
http://www.arl.army.mil

5.0 RESPONSE TECHNOLOGIES

Munitions and Explosives of Concern, which may include buried or abandoned munitions, UXO, or reactive or ignitable soil, not only pose explosive hazards but also present disposal challenges to personnel conducting munition response and cleanup. This chapter briefly discusses recovery in addition to treatment technologies. Recovery technologies are often dependent on the subsequent remediation technique. For example, blow-in-place requires no relocation of MEC; however, contained detonation chambers require movement of the MEC to a secondary location for safe disposal. See the following text box for a discussion of MEC relocation techniques.

Treatment technologies have been developed to destroy the reactive and/or ignitable material, reduce the amount of contaminated material at a site, remove the component of the waste that makes it hazardous, or immobilize the contaminant within the waste. However, different forms of energetic material require different technological approaches to their treatment and disposal. The types of hazards are divided into the following three categories:

- UXO
- Reactive and/or ignitable soils and debris
- Buried and abandoned munitions, including bulk explosives

The most commonly used technique for treating MEC at MRSs is in-place open detonation, also known as blow-in-place. In BIP, the explosive materials in MEC are detonated so that they no longer pose explosive hazards. It is often the preferred choice for managing MEC because of overarching safety concerns if the items were to be moved. However, BIP is controversial because of the concerns of the regulatory community and environmentalists that harmful emissions and residues will contaminate air, soils, and groundwater. This chapter also addresses several alternative treatments for MEC.

Reactive and/or ignitable residues found in soils at concentrations above 12 percent can pose hazards similar to those of the munitions themselves. The treatment of these wastes can be extremely difficult because they may be prone to detonate when disturbed or exposed to friction or heat, depending on the nature and extent of contamination. However, treatments have been developed that allow reactive and/or ignitable soil and debris to be decontaminated to levels that make it safe to dispose of them or leave them in place for in-situ remediation.

Excavating MEC

There are three general techniques used to excavate subsurface MEC once it is detected: **manual, mechanized,** and **remote control**. The selection of a retrieval method or, frequently, a combination of retrieval methods, is based on the types and characteristics of MEC detected, their depth, and site-specific soil and geological conditions. Retrieval actions should only be conducted by qualified workers after determination by a qualified EOD technician or UXO technician that the risk associated with movement is acceptable.

The only equipment used in **manual excavation** is shovels and/or other digging tools to move the top layers of soil. Manual excavation is extremely labor-intensive and can be hazardous to workers, as there is no barrier protecting them from an accidental explosion. When using manual retrieval methods in heavily vegetated areas, the vegetation should be removed in order to increase surface visibility and reduce the possibility of an accidental explosion. Also, additional MEC detection activities are usually performed when using these methods in order to confirm target removals and increase the probability of clearing all MEC in the area. Manual excavation methods are best suited for surface and near-surface MEC and are most effective when retrieving smaller items, such as small arms munitions, grenades, and small-caliber artillery projectiles. MEC located in remote areas, areas with saturated soils, and areas with steep slopes and/or forest may be best suited for manual methods. The retrieval of larger, more hazardous MEC items at greater subsurface depths should be reserved for mechanized retrieval methods, as the excavation involved is much more labor-intensive and hazardous.

Mechanized MEC retrieval methods involve the use of heavy construction equipment, such as excavators, bulldozers, and front-end loaders to remove overburden from the site. Excavation below the groundwater table might require pumping equipment. Mechanized methods are best suited for excavation efforts where large MEC items are buried at significant subsurface depths, such as 1-3 meters below ground surface. Mechanized methods work most efficiently in easy-to-access areas with dry soils. Site preparation, such as vegetation removal and the construction or improvement of access roads, may be required as well. In the future, mechanized methods may have a role in excavating heavily contaminated surface areas. It should also be noted that large excavation efforts, usually performed by mechanized methods, can have a significant negative impact on the environment, as they can destroy soil structure and disrupt nutrient cycling. It is important to note that although mechanized methods can be used, the final excavation is always done using the EOD technician manual methods so that the condition of the ordnance item can be assessed (fuzed or not fuzed), so the item can be identified, and so it can be determined if it is safe to move the item.

The effective use of **remote-controlled mechanized methods** generally requires site conditions similar to those required for mechanized excavation. The primary difference between the two methods is that remote-controlled systems are much safer because the operator of the system remains outside the hazardous area. Remotely controlled retrieval methods may involve the use of telerobotic and/or autonomous systems with navigation and position controls, typically a real-time differential global positioning system (DGPS). Differential global positioning system signals, however, can be obstructed by trees and dense vegetation, limiting the accuracy and implementability of remote-controlled systems.

Remote-controlled systems are still being developed and improved. Two remote-controlled systems were demonstrated at the Jefferson Proving Ground Technology Demonstration Program, Phase III. The systems were generally adept at excavating large items; however, they did not reduce the time or cost of MEC retrieval. Current systems have variable weather and terrain capabilities, but demonstrate better performance in relatively flat, dry, easy-to-access grassy or unvegetated areas.

5.1 Treatment and Disposal of MEC: An Overview

In-place open detonation, or blow-in-place (BIP), is the most commonly used method to destroy MEC. However, other techniques, such as incineration (small arms only), consolidated detonation, and contained detonation may be viable alternatives to blow-in-place, depending on the specific situation. In addition, bioremediation (in-situ, windrow composting, and bioslurry methods), low-temperature thermal desorption, wet air oxidation, and plasma arc destruction are alternatives that can be applied to reactive and/or ignitable soils. Each technology or combination of technologies has different advantages and disadvantages. A combination of safety, logistical, throughput, and cost issues often determines the practicality of treatment technologies.

Significant statutory and regulatory requirements may apply to the destruction and treatment of all MEC (see Chapter 2, "Regulatory Overview"). The particular requirements that will be either most applicable or most relevant and appropriate to MEC remediation are the Federal and State RCRA substantive requirements for open burning and open detonation (OB/OD) and incineration. While the regulations may vary among States and individual sites, they generally include stringent closure requirements for sites at which OB/OD is used, trial burn tests prior to operating incinerators, and a variety of other requirements. Familiarity with the State and Federal requirements will be critical in determining your approach to munitions response.

Table 5-1 summarizes the effective uses of treatment technologies for remediating MEC and munitions constituents found in soils and debris. These technologies are addressed in more detail in subsequent sections of this chapter. Readers should note that many of these treatment technologies are not standard practice for munitions responses. Some technologies are currently used primarily at industrial facilities, while others are still in the early stages of development. However, when appropriate, alternatives to blow-in-place should be considered in the evaluation of alternatives for the munitions response. The evaluation of treatment technologies will vary from site to site and will depend on several factors, including, but not limited to:

- Safety considerations
- Scale of project (or throughput)
- Cost and cost-effectiveness
- Size of material to be treated and capacity of technology
- Logistics considerations such as accessibility of range and transportability of technology
- CERCLA nine criteria remedy evaluation and selection process

Table 5-1. Overview of Remediation Technologies for Explosives and Residues

Explosive Problem	Treatment Options	Situations/Characteristics That Affect Treatment Suitability
Munitions or fragments contaminated with munitions residue	Open burning (OB)	Limits the explosive hazard to the public and response personnel. Inexpensive and efficient, but highly controversial due to public and regulator concern over health and safety hazards. Noise issues. Significant regulatory controls. Used infrequently at MRSs. Historically, used primarily for bulk explosives.
Munitions or fragments contaminated with munitions residue	Open detonation (OD)	Limits the explosive hazard to the public and response personnel. Inexpensive and efficient, similar to OB, but OD is generally cleaner. This technique can be used to dispose of higher order explosives. A characteristic of OD is complete, unconstrained detonation, which does not allow for the creation of intermediaries and, if successfully implemented, results in more complete combustion. Residuals from donor charges may present a concern.
Variable caliber munitions	Contained detonation chamber	Significantly reduces noise and harmful emissions, as well as the overpressure, shock wave, and fragmentation hazards of OB/OD. Available as transportable units. Actual case throughput of a nontransportable unit destroyed 12,500 projectiles (155 mm in size) in 1 year.
Small-caliber munitions or fragments, debris, soil, and liquid waste	Rotary kiln incinerator	Generally effective for removing explosives and meeting regulatory response requirements. Requires large capital investment, especially incinerators that can handle detonation. For incinerators that treat soil, quench tanks clog frequently; clayey, wet soils jam feed systems; and cold conditions exacerbate clogging problems. Controversial due to regulator and public concerns over air emissions and ash byproducts. Nonportable units require transport of all material to be treated, which can be dangerous and costly. Project scale should be considered. Average throughput is 8,700 pounds of 20 mm ammunition per 15-hour operating day.
Small-caliber munitions or fragments, soil	Deactivation furnace	Thick-walled primary combustion chamber withstands small detonations. Renders munitions unreactive. The average throughput is 8,700 pounds of 20 mm ammunition per 15-hour operating day.
Munitions or fragments, soil, and debris	Safe deactivation of energetic materials and beneficial use of byproducts	Still under development. At low temperatures, reacts explosives with organic amines that neutralize the explosives without causing detonation. Some of the liquid byproducts have been found to be effective curing agents for conventional epoxy resins. Low or no discharge of toxic chemicals.
Soil and debris	Wet air oxidation	Treats slurries containing reactive and/or ignitable material. Very effective in treating RDX; however, may produce hazardous byproducts and gaseous effluents that require further treatment. High capital costs and frequent downtime.
Soil (munitions constituents residue)	Windrow composting	Microorganisms break down reactive and/or ignitable residues into less reactive substances. Requires relatively long time periods and large land areas. Highly effective and low process cost, but ineffective with extremely high concentrations of explosives.

Table 5-1. Overview of Remediation Technologies for Explosives and Residues (continued)

Explosive Problem	Treatment Options	Situations/Characteristics That Affect Treatment Suitability
Soil (munitions constituents residue)	Bioslurry (soil slurry biotreatment)	Optimizes conditions for maximum microorganism growth and degradation of reactive and/or ignitable material. Slurry processes are faster than many other biological processes and can be either aerobic or anaerobic or both, depending on contaminants and remediation goals. Effective on soil with high clay content. In general, treated slurry is suitable for direct land application.
Soil/ Groundwater (Munitions constituents residue)	Bioremediation	Conditions are maintained that promote growth of microorganisms that degrade reactive and/or ignitable compounds. May not be effective in clayey or highly layered soils and can take years to achieve cleanup goals. Chlorinated compounds may be difficult to degrade.
Soil/ Groundwater (Munitions constituents residue)	Chemical remediation	Chemicals are pushed into a medium through injection wells or delivered by pipes or sprinklers to shallow contaminated soils. These chemicals oxidize/reduce reactive and/or ignitable compounds, transforming them to non-toxic compounds. Some reagents may be dangerous.
Soil (Munitions constituents residue)	Soil washing	Reduces the total volume of contaminated soil and removes reactive and/or ignitable compounds from soil particles. Requires additional treatment for wastewater and, potentially, for treated soils.
Soil (Munitions constituents residue)	Low-temperature thermal desorption	Used to treat soils with low concentrations of some reactive and/or ignitable material. Contaminated soil is heated to separate contaminants by volatilizing them. They are then destroyed. Not very effective for treating explosives.
Equipment, debris, and scrap	Hot gas decontamination	Process uses heated gas to clean reactive and/or ignitable residue from equipment and scrap. The system is designed to clean up to 1 pound of total explosives from 3,000 pounds of material. The advantage of this system is that it does not destroy the equipment it cleans.
Debris and scrap	Base hydrolysis	Process uses heated acid to clean reactive and/or ignitable residue from material. This system can be designed to accommodate a range of throughput needs.

Note**:** This table is not exhaustive. Each of the treatment technologies is discussed in more detail in the succeeding pages.

5.1.1 Safe Handling of MEC

The safety of handling MEC depends on the types of munitions found and the site-specific situation. There is no single approach for every munition, or every site. The complete identification and disarming of munitions is often dangerous and difficult, if not impossible. In most cases, the safest method to address munition items is open detonation (OD) using blow-in-place (BIP) methods. This is particularly true when the munition is located in an area where its detonation would not place the public at risk. It is most appropriate when the munition or its fuzing mechanism cannot be identified, or identification would place a response worker at unacceptable risk. Great weight and deference will be given, with regard to the appropriate treatment, to the explosives safety expertise of on-site technical experts. When required, DDESB-approved safety controls (e.g., sandbagging) can be used to provide additional protection to potential harmful effects of BIP. In cases in which experts determine that BIP poses an unacceptable risk to the public or critical assets (e.g., natural or cultural resources) and the risk to workers is acceptable, munitions items may be transported to another, single location for consolidated detonation. This location is one where the threats to the critical assets and the public can be minimized. Such transport must be done carefully under the supervision of experts, taking into account safety concerns. Movement with remote-control systems sometimes will be appropriate to minimize danger to personnel. Instead of detonating all MEC items in place, consolidated treatment allows for improved efficiency and control over the destruction (e.g., safe zones surround the OD area; blast boxes and burn trays are used).

5.1.2 Render-Safe Procedures

In rare cases when munitions pose an immediate, certain, and unacceptable risk to personnel, critical operations, facilities, or equipment, as determined by on-scene EOD personnel, render-safe procedures (RSPs) may be performed to reduce or eliminate the explosive hazards. For ordnance of questionable condition, RSPs may be unsafe, are not 100 percent effective, and can result in an accidental high-order detonation. RSPs are conducted by active duty military EOD experts and typically involve disarming MEC (removing or disabling the fuze and/or detonator), or using specialized procedures. Such procedures can dramatically increase explosives safety risks to EOD personnel, and DoD considers their use only in the most extraordinary circumstances. During these procedures, blast mitigation factors are taken into account (i.e., distance and engineering controls), and EOD personnel disarm the MEC items and move them from the location at which they were found to a central area on-site for destruction.

5.2 Treatment of MEC

5.2.1 Open Detonation

In most situations, open detonation (OD) remains the safest and most frequently used method for treating UXO. When open detonation takes place where UXO is found, it is called blow-in-place. In munitions response, demolition is almost always conducted on-site, most frequently in the place it is found, because of the inherent safety concerns and the regulatory restrictions on transporting even disarmed explosive materials. Blow-in-place detonation is accomplished by placing and detonating a donor explosive charge next to the munition which causes a sympathetic detonation of the munition to be disposed of. Blow-in-place can also be accomplished using laser-initiated techniques and is considered by explosives safety experts to be the safest, quickest, and most cost-effective remedy for destroying UXO.

When open detonation takes place in an area other than that where the UXO was found, it is called consolidated detonation. In these cases, experts have determined that the location of the UXO poses an unacceptable risk to the public or critical assets (e.g., a hospital, natural or cultural resources, historic buildings) if it is blown in place. If the risk to the workers is deemed acceptable and the items can be moved, the munitions will be relocated to a place on-site that has minimal or no risk to the public or critical assets. Typically, when consolidated detonations are used on a site, multiple munition items are consolidated into one "shot" to minimize the threat to the public of multiple detonations. The decision to move the UXO from the location in which it is found is made by the explosives safety officer and is based on an assessment that the risks to workers and others in moving this material is acceptable. Movement of the UXO is rarely considered safe, and the safety officer generally tries to minimize the distance moved.

Open Detonation and DMM

Discarded Military Munitions are frequently tracked in the same manner as UXO and blown in place. However, it may be less risky to move DMM elsewhere. If there is any doubt about whether a munitions item is DMM or UXO, it must be tracked as if it is UXO.

Increasing regulatory restrictions and public concern over its human health and environmental impacts may create significant barriers to conducting open detonation in both BIP and consolidation detonation in the future. The development of alternatives to OD in recent years is a direct result of these growing concerns and increased restrictions on the use of OD (see text box on following page).

There are significant environmental and technical challenges to treating ordnance and explosives with OD.[71] These limitations include the following:

- **Restrictions on emissions** — Harmful emissions may pose human health and environmental risks and are difficult to capture sufficiently for treatment. Areas with emissions limitations may not permit OD operations.
- **Soil and groundwater contamination** — Soil and groundwater can become contaminated with byproducts of incomplete combustion and detonation as well as with residuals from donor charges.
- **Area of operation** — Large spaces are required for OD operations in order to maintain minimum distance requirements for safety purposes (see Chapter 6, "Explosives Safety").
- **Location** — Environmental conditions may constrain the use of OD. For example, in OD operations, emissions must be carried away from populated areas, so prevailing winds must be steady. Ideal wind speeds are 4-15 mph, because winds at these speeds are not likely to change direction and they tend to dissipate smoke rapidly. In addition, any type of storm (including sand, snow, and electrical) that is capable of producing static electricity can potentially cause premature detonation.

[71] U.S. EPA Office of Research and Development. *Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes*, Handbook, September 1993.

- **Legal restrictions** — Legal actions and regulatory requirements, such as restrictions on RCRA Subpart X permits, emissions restrictions, and other restrictions placed on OD, may reduce the use of OD in the future. However, for munitions responses addressed under CERCLA, no permits are currently required.
- **Noise** — Extreme noise created by a detonation limits where and when OD can be performed.

The Debate Over OD

Because of the danger associated with moving MEC, the conventional wisdom, based on DoD's explosive safety expertise, is to treat UXO on-site using OD, usually blow-in-place. However, coalitions of environmentalists, Native Americans, and community activists across the country have voiced concerns and filed lawsuits against military installations that perform OB/OD for polluting the environment, endangering their health, and diminishing their quality of life. While much of this debate has focused on high-throughput industrial facilities and active ranges, and not on the practices at ranges, similar concerns have also been voiced at ranges. Preliminary studies of OD operations at Massachusetts Military Reservation revealed that during the course of open detonation, explosive residues are emitted in the air and deposited on the soil in concentrations that exceed conservative action levels more than 50 percent of the time. When this occurs, some response action or cleanup is required. It is not uncommon for these exceedances to be significantly above action levels.

Several debates are currently underway regarding the use of blow-in-place OD ranges. One debate is about whether OD is in fact a contributor to contamination and the significance of that contribution. A second debate is whether a contained detonation chamber (CDC) is a reasonable alternative that is cleaner than OD (albeit limited by the size of munitions it can handle, and the ability to move munitions safety). Another study at Massachusetts Military Reservation revealed that particulates trapped in the CDC exhaust filter contain levels of chlorinated and nitroaromatic compounds that must be disposed of as hazardous waste, thus suggesting the potential for hazardous air emissions in OD. The pea gravel at the bottom of the chamber, after repeated detonations, contains no detectable quantities of explosives, thus suggesting that the CDC is highly effective. The RPM at Massachusetts Military Reservation has suggested that when full life-cycle costs of OD are considered, including the cost of response actions at a number of the OD areas, the cost of using OD when compared to a CDC may be even more.

Additional information will help shed light on the costs and environmental OD versus CDC. The decision on which alternative to use, however, will involve explosive safety experts who must decide that the munitions are safe to move if they will be detonated in a CDC. In addition, current limitations on the size of munitions that can be handled in a CDC must also be considered.

UXO Model Clearance Project

In 1996 the U.S. Navy conducted a UXO Model Clearance Project at Kaho`olawe Island, Hawaii, that demonstrated the effectiveness of using protective works to minimize the adverse effects of detonation in areas of known cultural and/or historical resources. The results of the demonstrations and practical applications revealed that if appropriate protective works are used, the adverse effects of the blast and fragments resulting from a high-order UXO detonation are not as detrimental as originally anticipated. Protective works are physical barriers designed to limit, control, or reduce adverse effects of blast and fragmentation generated during the high-order detonation of UXO. Protective works used at Kaho`olawe included: tire barricades, deflector shields, trenches/pits, directional detonations, fragmentation blankets, and plywood sheets.

Source: UXO Model Clearance Report, Kaho`olawe Island, Hawaii, Protective Works Demonstration Report. Prepared for U.S. Navy Pacific Division Naval Facilities, Engineering Command, Kapolei, Ha. Contract No. N62742-93-D-0610 1996.

In open detonation, an explosive charge is used to create a sympathetic detonation in the energetic materials and munitions to be destroyed. Engineering controls and protective measures can be used, when appropriate, to significantly reduce the effects and hazards associated with blast and high-speed fragments during OD operations. Common techniques for reducing these effects include constructing berms and barricades that physically block and/or deflect the blast and fragments, tamping the explosives with sandbags and/or earth to absorb energy and fragmentation, using blast mitigation foams, and trenching to prevent transmission of blast-shock through the ground. These methods have been effective in reducing the size of exclusion zones required for safe OD and limiting local disruptions due to shock and noise. In some instances (e.g., low-explosive-weight MEC), well-engineered protective measures can reduce the effects and hazards associated with OD to levels comparable to contained detonation chambers (see Section 5.2.3.2).

5.2.2 Open Burning

Although open burning (OB) and open detonation (OD) are often discussed together, they are not often used at the same time. In fact, the use of open burning is limited today due to significant air emissions released during burning and strict environmental regulations that many times prohibit this. The environmental and technical challenges to using OB are the same as those listed in Section 5.2.1 for OD. When OB is used, it is usually applied to munitions areas for treatment of bulk explosives or excess propellant. OB operations have been implicated in the release of perchlorate into the environment, specifically groundwater.

5.2.3 Alternative Treatment Technologies

Because of growing concern and regulatory constraints on the use of OD, alternative treatments have been developed that aim to be safer, commercially available or readily constructed, cost-effective, versatile in their ability to handle a variety of energetics, and able to meet the needs of the Army.[72] Although some of these alternative treatments have applicability for field use, the majority are designed for industrial-level demilitarization of excess or obsolete munitions that have not been used.

5.2.3.1 *Incineration*

Incineration is primarily used to treat soils containing reactive and/or ignitable compounds. In addition, small quantities of MEC, bulk explosives, and debris containing reactive and/or ignitable material may be treated using incineration. Most MEC is not suitable for incineration. This technique may be used for small-caliber ammunition (less than 0.50 caliber), but even the largest incinerators with strong reinforcement cannot handle the detonations of very large munitions. Like OB/OD, incineration is not widely accepted by regulators and the public because of concerns over the

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[72] J. Stratta et al. *Alternatives to Open Burning/Open Detonation of Energetic Materials*, U.S. Army Corps of Engineers, Construction Engineering Research Lab, August 1998.

environmental and health impacts of incinerator emissions and residues.

The strengths and weaknesses of incineration are summarized as follows:

- **Effectiveness** — In most cases, incineration reduces levels of organics to nondetection levels, thus simplifying response efforts.
- **Proven success** — Incineration technology has been used for years, and many companies offer incineration services. In addition, a diverse selection of incineration equipment is available, making it an appropriate operation for sites of different sizes and containing different types of contaminants.
- **Safety issues** — The treatment of hazardous and reactive and/or ignitable materials with extremely high temperatures is inherently hazardous.
- **Emissions** — Incinerator stacks emit compounds that may include nitrogen oxides (NO_x), volatile metals (including lead) and products of incomplete combustion.
- **Noise** — Incinerators may have 400 to 500-horsepower fans, which generate substantial noise, a common complaint of residents living near incinerators.
- **Costs —** The capital costs of mobilizing and demobilizing incinerators can range from $1 million to $2 million. However, on a large scale (above 30,000 tons of soil treated), incineration can be a cost-effective treatment option. Specifically, at the Cornhusker Army Ammunition Plant, 40,000 tons of soil were incinerated at an average total cost of $260 per ton. At the Louisiana Army Ammunition Plant, 102,000 tons of soil were incinerated at $330 per ton.[73]
- **Public perception** — The public generally views incineration with suspicion and as a potentially serious health threat caused by possible emission of hazardous chemicals from incinerator smokestacks.
- **Trial burn tests** — An incinerator must demonstrate that it can remove 99.99 percent of organic material before it can be permitted to treat a large volume of hazardous waste.
- **Ash byproducts** — Like OB/OD, most types of incineration produce ash that contains high concentrations of inorganic contaminants.
- **Materials handling** — Soils with a high clay content can be difficult to feed into incinerators because they clog the feed mechanisms. Often, clayey soils require pretreatment in order to reduce moisture and viscosity.
- **Resource demands** — Operation of incinerators requires large quantities of electricity and water.

The most commonly used type of incineration system is the rotary kiln incinerator. Rotary kilns come in different capacities and are used primarily for soils and debris contaminated with reactive and/or ignitable material. Rotary kilns are available as transportable units for use on-site, or as permanent fixed units for off-site treatment. When considering the type of incinerator to use at your site, one element that you should consider is the potential risk of transporting reactive and/or ignitable materials.

The rotary kiln incinerator is equipped with an afterburner, a quench, and an air pollution

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[73]U.S. EPA, Office of Research and Development. *Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes*, Handbook, September 1993.

control system to remove particulates and neutralize and remove acid gases. The rotary kiln serves as a combustion chamber and is a slightly inclined, rotating cylinder that is lined with a heat-resistant ceramic coating. This system has had proven success in reducing contamination levels to destruction and removal efficiencies (DRE) that meet RCRA requirements (40 CFR 264, Subpart O).[74] Specifically, reactive and/or ignitable soil was treated on-site at the former Nebraska Ordnance Plant site in Mead, Nebraska, using a rotary kiln followed by a secondary combustion chamber, successfully reducing constituents of concern that included TNT, RDX, TNB, DNT, DNB, HMX, tetryl, and NT to DRE of 99.99 percent.[75]

For deactivating large quantities of small arms munitions at industrial operations (e.g., small arms cartridges, 50-caliber machine gun ammunition), the Army generally uses deactivation furnaces. Deactivation furnaces have a thick-walled primary detonation chamber capable of withstanding small detonations. In addition, they do not completely destroy the vaporized reactive and/or ignitable material, but rather render the munitions unreactive.[76]

For large quantities of material, on-site incineration is generally more cost-effective than off-site treatment, which includes transportation costs. The cost of soil treatment at off-site incinerators ranges from $220 to $1,100 per metric ton (or $200 to $1,000 per ton).[77] At the former Nebraska Ordnance Plant site, the cost of on-site incineration was $394 per ton of contaminated material.[78] Two major types of incinerators used by the Army are discussed in Table 5-2. While incineration is used most often in industrial operations, it may be considered in the evaluation of alternatives for munitions responses as well.

The operation and maintenance requirements of incineration include sorting and blending wastes to achieve levels safe for handling (below 12 percent explosive concentration for soils), burning wastes, and treating gas emissions to control air pollution. Additional operation and maintenance factors to consider include feed systems that are likely to clog when soils with high clay content are treated, quench tanks that are prone to clog from slag in the secondary combustion chamber, and the effects of cold temperatures, which have been known to exacerbate these problems.

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[74]U.S. EPA, Office of Solid Waste and Emergency Response, Technology Innovation Office. *On-Site Incineration at the Celanese Corporation Shelby Fiber Operations Superfund Site, Shelby, North Carolina*, October 1999.

[75]Federal Remediation Technologies Roundtable. *Incineration at the Former Nebraska Ordnance Plant Site, Mead, Nebraska*, Roundtable Report, October 1998.

[76]U.S. EPA, Office of Research and Development. *Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes*, Handbook, September 1993.

[77] DoD, Environmental Technology Transfer Committee. *Remediation Technologies Screening Matrix and Reference Guide*, Second Edition, October 1994.

[78]Federal Remediation Technologies Roundtable, *Incineration at the Former Nebraska Ordnance Plant Site, Mead, Nebraska*, Roundtable Report, October 1998.

Table 5-2. Characteristics of Incinerators

Incinerator Type	Description	Operating Temps	Strengths and Weaknesses	Effective Uses
Rotary Kiln	A rotary kiln is a combustion chamber that may be designed to withstand detonations. The secondary combustion chamber destroys residual organics from off-gases. Off-gases then pass into the quench tank for cooling. The air pollution control system consists of a venturi scrubber, baghouse filters, and/or wet electrostatic precipitators, which remove particulates prior to release from the stack.	Primary chamber – Gases: 800-1,500 EF Soils: 600-800 EF Secondary chamber – Gases: 1,400-1,800 EF	Renders munitions unreactive. Debris or reactive and/or ignitable materials must be removed from soils prior to incineration; quench tank clogs; clayey, wet soils can jam the feed system; cold conditions exacerbate clogging problems. Requires air pollution control devices.	Commercially available for destruction of bulk explosives and small MEC, as well as contaminated soil and debris.
Deactivation Furnace	Designed to withstand small detonations from small arms. Operates in a manner similar to the rotary kiln except it does not have a secondary combustion chamber.	1,200-1,500 EF	Renders munitions unreactive.	Large quantities of small arms cartridges, 50-caliber machine gun ammunition, mines, and grenades.

Source: U.S. EPA, Office of Research and Development. *Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes*, Handbook, September 1993.

New incineration systems under development include a circulating fluidized bed that uses high-velocity air to circulate and suspend waste particles in a combustion loop. In addition, an infrared unit uses electrical resistance heating elements or indirect-fired radiant U-tubes to heat material passing through the chamber on a conveyor belt.

5.2.3.2 *Contained Detonation Chambers*

Contained detonation chambers (CDCs) are capable of repeated detonations of a variety of ordnance items, with significant reductions in the air and noise pollution problems of OD; however, the use of CDCs assumes that the munition item is safe to move. CDCs, or blast chambers, are used by the Army at a few ammunition plants to treat waste pyrotechnics, explosives, and propellants. In addition, several types of transportable detonation chambers are available for emergency responses for small quantities of MEC. In general, blast chambers do not contain all of the detonation gases, but vent them through an expansion vessel and an air pollution control unit. Such a vented system minimizes the overpressure and shock wave hazards. In addition, CDCs contain debris from detonations as well, eliminating the fragmentation hazards.

Several manufacturers have developed CDCs for both commercial and military use. However, DoD has not implemented CDCs at many military installations because of safety issues relating to the moving of munitions, rate of throughput, transportability, and cost.

Both industrial-level (fixed) and mobile (designed for use in the field) CDCs display a range of capabilities. CDCs designed for field use are limited in the amount of explosives they can contain, the types of munitions they can handle, and their throughput capability. Portable units have size constraints and are not designed to destroy munitions larger than 81 mm HE or 10 pounds of HMX, but the nonportable units can handle munitions up to 155 mm or 100 pounds of HMX (130 lb TNT equivalent).[79]

5.3 Treatment of Soils That Contain Reactive and/or Ignitable Compounds

Some of the technologies described in Section 5.2 can also be used to treat reactive and/or ignitable soil (e.g., thermal treatment). However, there are a number of alternative treatment technologies that are specifically applicable to soils containing reactive and/or ignitable materials. These are described in the sections that follow.

5.3.1 Biological Treatment Technologies

Biological treatment, or bioremediation, is a broad category of systems that use microorganisms to decompose reactive and ignitable residues in soils into byproducts such as water and carbon dioxide. Bioremediation includes ex-situ treatments such as composting and slurry reactor biotreatment that require the excavation of soils and debris, as well as in-situ methods such as bioventing, monitored natural attenuation, and nutrient amendment. Bioremediation is used to treat large volumes of contaminated soils, and it is generally more publicly accepted than incineration. However, highly contaminated soils may not be treatable using bioremediation or may require pretreatment, because high concentrations of reactive and/or ignitable materials, heavy metals, or inorganic salts are frequently toxic to the microorganisms that are the foundation of biological systems. Blending highly reactive material with clean soil is frequently used to ensure that the explosive content of the soil is below 10 percent. This is not considered treatment but rather is a preparation technique to allow the waste to be safely treated.

While biological treatment systems generally require significantly lower capital investments than incinerators or other technology-intensive systems, they also often take longer to achieve cleanup goals. Therefore, the operation and monitoring costs of bioremediation must be taken into account. Because bioremediation includes a wide range of technological options, its costs can vary dramatically from site to site. The benefits and limitations of bioremediation include the following:

- **Easily implemented** — Bioremediation systems are simple to operate and can be implemented using commercially available equipment.
- **Relatively low costs** — In general, the total cost of bioremediation is significantly less than more technology-intensive treatment options.
- **Suitability for direct land application** — In general, soil treated using most bioremediation systems is suitable for land application.
- **Limited concentrations of reactive and/or ignitable materials and other contaminants** — Soil with very high levels of reactive and/or ignitable material may not

[79] DeMil International, Inc. *The "Donovan Blast Chamber" Technology for Production Demilitarization at Blue Grass Army Depot and for UXO Remediation*, Paper presented at the Global Demilitarization Symposium and Exhibition, 1999.

be treatable using bioremediation, so pretreatment to reduce contaminant levels **may be** required. In addition, the presence of other contaminants, such as metals, may render bioremediation ineffective.

- **Temperature limitations** — Cold temperatures limit the effectiveness of bioremediation.
- **Resource demands** — With the exception of bioslurry treatments, bioremediation systems require large land areas. In addition, many biological treatment systems require substantial quantities of water to maintain adequate moisture levels.
- **Long time frame** — With the exception of bioslurry treatments, bioremediation systems may require long time periods to degrade reactive and/or ignitable materials.
- **Post-treatment** — In some systems, process waters and off-gases may require treatment prior to disposal.[80]

There are many different options to choose from in selecting your biological treatment systems, but your selection will depend on the following factors:

- Types of contaminants
- Soil type
- Climate and weather conditions
- Cost and time constraints
- Response goals at your site

Biological treatment systems that are available can be in-situ and can be open or closed, depending on air emission standards. Other available features include irrigation to maintain optimal moisture and nutrition conditions, and aeration systems to control odors and oxygen levels in aerobic systems. In general, bioremediation takes longer to achieve cleanup goals than incineration.

Biological treatment can be conducted in-situ or ex-situ; however, because reactive and/or ignitable materials in the soil are usually not well mixed, removing them for ex-situ treatment is usually recommended, as the removal process results in thorough mixing of the soil, increasing the uniformity of degradation. Also, the likelihood of migration of reactive and/or ignitable materials and their breakdown products is reduced with controlled ex-situ remediation of removed soils. Both ex-situ and in-situ treatment systems are discussed below.

5.3.1.1 *Monitored Natural Attenuation*

Monitored natural attenuation (MNA) is a response action that relies on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a timeframe that is reasonable compared to that offered by more active methods.[81]

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[80]DoD, Environmental Technology Transfer Committee, Remediation Technologies Screening Matrix and Reference Guide, Second Edition, October 1994.

[81]U.S. EPA, Office of Solid Waste and Emergency Response. *Use of Monitored Natural Attenuation at Superfund RCRA Corrective Action and Underground Storage Tank Sites*, OSWER Directive 9200.4-17, November 1997.

Monitored natural attenuation uses microbes already present in the soil or groundwater to degrade contaminants. It is never a default or presumptive remedy, but is carefully evaluated prior to selection. The burden of proof as to whether MNA is appropriate rests with the party proposing MNA. EPA's directive on the use of MNA at sites requires substantial analysis and continuous monitoring to prove that MNA can achieve cleanup goals on the particular chemicals of concern within a reasonable timeframe when compared to other response methods. In addition to a comparable timeframe, MNA may be appropriate when plumes are no longer increasing (or are shrinking), and/or when used in conjunction with active remediation measures (e.g., source control, sampling, and treating of hot spots). Monitored natural attenuation is currently employed at several groundwater sites containing reactive and/or ignitable compounds. Louisiana Army Ammunition Plant has used MNA to reduce TNT and RDX in groundwater. Initial results show a marked decrease in both of those compounds. The suitability to use MNA for explosive compounds must be carefully evaluated based on site-specific factors, since explosive compounds do not act in the same manner as the solvents for which MNA has been most frequently used.

5.3.1.2 *Composting*

Composting is an ex-situ process that involves tilling the contaminated soils with large quantities of organic matter and inorganic nutrients to create a microorganism-rich environment. An organic agent such as straw, sawdust, or wood chips is usually added to increase the number of microorganism growth sites and to improve aeration. Additional nutrient-rich amendments may be added to maximize the growth conditions for microorganisms and therefore the efficiency with which reactive and/or ignitable compounds biodegrade.

Figure 5-1. Windrow Composting

In **windrow composting**, the soil mixture is layered into long piles known as windrows. Each windrow is mixed by turning with a composting machine as shown in Figure 5-1. Figures 5-2 and 5-3 provide schematic diagrams of a typical windrow composting process and system.

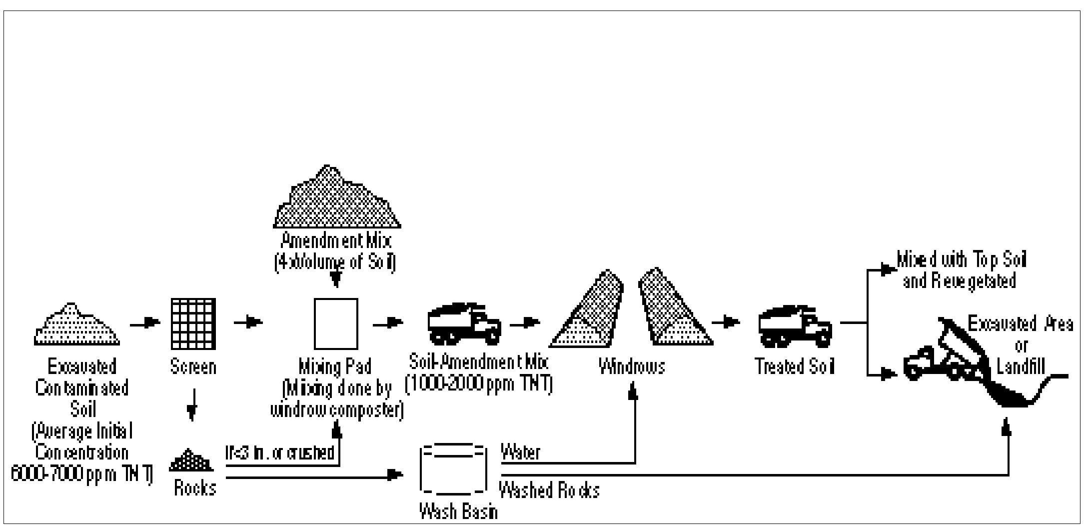

Figure 5-2. Typical Windrow Composting Process

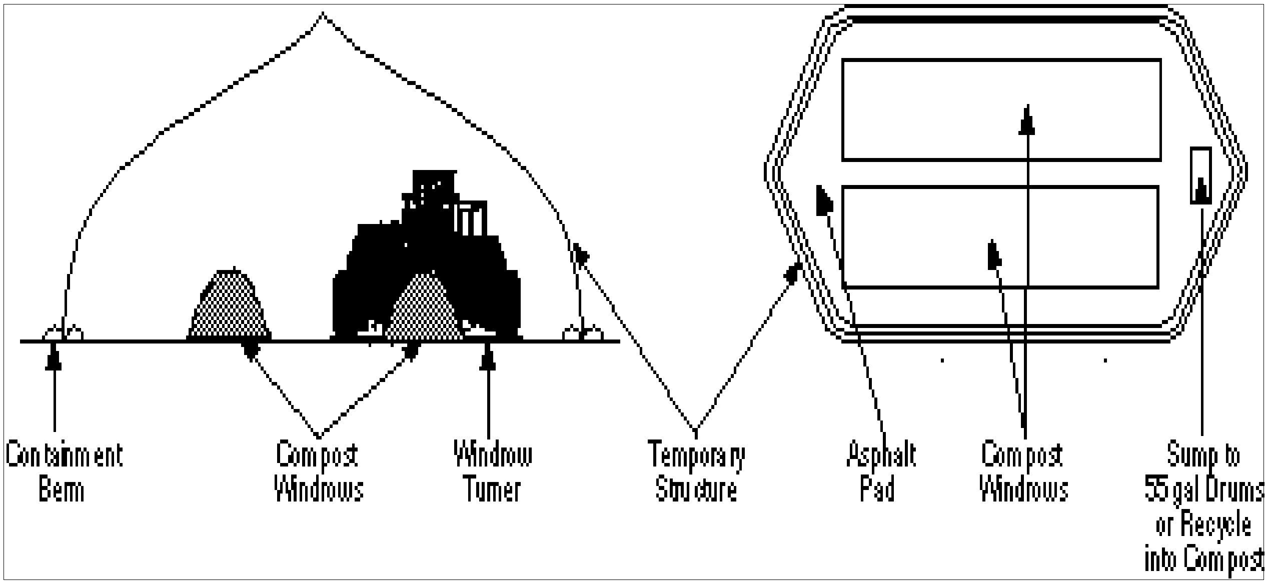

Figure 5-3. Side and Top View of Windrow Composting System

Windrow composting has proved to be highly successful in achieving cleanup goals at a field demonstration at the Umatilla Army Depot Activity in Hermiston, Oregon.[82] At Umatilla, soil was mixed with soil amendments and composted in both aerated and nonaerated windrows for a total of 40 days. The resulting compost generally reduced the levels of the target explosives (TNT, RDX, and HMX) to below cleanup goals. Specifically, TNT reductions were as high as 99.7 percent at 30 percent soil in 40 days of operation, with the majority of removal occurring in the first 20 days. Destruction and removal efficiencies for RDX and HMX were 99.8 and 96.8 percent, respectively. The field demonstration showed the relative simplicity and cost-effectiveness of windrow composting when compared with nonbiological treatment technologies.

5.3.1.3 *Soil Slurry Biotreatment*

Soil slurry biotreatment (also known as **bioslurry** or **slurry reactor treatment)** is an ex-situ process that involves the submersion of contaminated soils or sludge in water in a tank, lagoon, or bioreactor to create a slurry (Figure 5-4). The nutrient content, pH, and temperature are carefully controlled, and the slurry is agitated to maximize the nutrient, microorganism, and contaminant contact. Because the conditions are optimized for the microorganisms, slurry processes are faster than those in many other biological processes and, therefore, the operation and maintenance (O&M) costs are lower than in other biological processes. However, the highly controlled environment requires capital investments beyond those of other biological treatment systems. The treated slurry can be used directly on land without any additional treatment.

Figure 5-4. Slurry Reactor

[82]Federal Remediation Technologies Roundtable. *Technology Application Analysis: Windrow Composting of Explosives Contaminated Soil at Umatilla Army Depot Activity*, Hermiston, Oregon, October 1998.

Bioslurry treatment can be conducted under both aerobic and anaerobic conditions. In aerobic bioslurry, the oxygen content is carefully controlled. In anaerobic bioslurry, anaerobic bacteria consume the carbon supply, resulting in the depletion of oxygen in the soil slurry. Findings of a field demonstration at the Joliet Army Ammunition Plant demonstrated that maximum removal of reactive and/or ignitable materials occurred with operation of a slurry reactor in an aerobic-anaerobic sequence, with an organic cosubstrate, operated in warm temperatures. The same demonstration project showed that bioslurry treatment can remove TNT, RDX, TNB, and DNT to levels that meet a variety of treatment goals.[83] Soil slurry biotreatment is expected to cost about one-third less than incineration.[84] The primary limitations of soil slurry biotreatment include the following:

- **Soil excavation** — Soils must be excavated prior to treatment.
- **Pretreatment requirements** — Nonhomogeneous soils can potentially lead to materials-handling problems; therefore, pretreatment of soils is often necessary to obtain uniformly sized materials.
- **Post-treatment** — Dewatering following treatment can be costly, and nonrecycled wastewaters must be treated before being disposed of.
- **Emissions** — Off-gases may require treatment if volatile compounds are present.

5.3.1.4 *In-Situ Chemical and Biological Remediation*

Treating contaminated soils in-situ involves the introduction of microbes (enhanced or augmented bioremediation), or the addition of nutrients with the intention of inducing a suitable environment for the biological degradation of pollutants. Alternatively, selected reactive compounds may be introduced into the soil to chemically transform reactive and/or ignitable compounds through oxidative or reductive processes. For aqueous media, hydrogen peroxide, oxygen release compounds (e.g., magnesium peroxide), ozone, or microorganisms are added to the water to degrade reactive and/or ignitable materials more rapidly. Depending on the depth of the contaminants, spray irrigation may be used, or for deeper contamination, injection wells may be used. The primary advantage of in-situ remediation is that soils do not need to be excavated or screened prior to treatment, thus resulting in cost savings. In addition, soils and groundwater can be treated simultaneously. The primary limitation of in-situ remediation is that it may allow reactive and/or ignitable materials to migrate deeper into the soil or into the groundwater under existing site-specific hydrodynamic conditions. Other limitations of this type of remediation include the following:

- There is a high degree of uncertainty about the uniformity of treatment and a long treatment period may be required.
- Nutrient and water injection wells may clog frequently.
- The heterogeneity of soils and preferential flow paths may limit contact between injected fluids and contaminants.
- The method should not be used for clay, highly layered, or highly heterogeneous subsurface environments (such as complex karst or fractured rock subsurface formations).

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[83] J.F. Manning, R. Boopathy, and E.R. Breyfogle. *Field Demonstration of Slurry Reactor Biotreatment of Explosives-Contaminated Soils*, 1996.

[84] DoD Environmental Technology Transfer Committee. *Remediation Technologies Screening Matrix and Reference Guide*, Second Edition, October 1994.

- High concentrations of heavy metals, highly chlorinated organics, long-chain hydrocarbons, or inorganic salts are likely to be toxic to microorganisms.
- The method is sensitive to temperature (i.e., it works faster at high temperatures and slower at colder temperatures).
- The use of certain reagents (e.g., Fenton's reagent) can create potentially hazardous conditions.

5.3.2 Soil Washing

Soil washing is a widely used treatment technology that reduces contaminated soil volume and removes contamination from soil particles. Reactive and/or ignitable materials are removed from soils by separating contaminated particles from clean particles using particle size separation, gravity separation, and attrition scrubbing. The smaller particles (which generally are the ones to which reactive and/or ignitable materials adhere) are then treated using mechanical scrubbing, or are dissolved or suspended and treated in a solution of chemical additives (e.g., surfactants, acids, alkalis, chelating agents, and oxidizing or reducing agents) or treated using conventional wash-water treatment methods. In some cases, the reduced volume of contaminated soil is treated using other treatment technologies, such as incineration or bioremediation. Following soil washing, the contaminated wash water is treated using wastewater treatment processes.

Soil washing is least effective in soils with large amounts of clay and organic matter to which reactive and/or ignitable materials bind readily. Soil washing systems are transportable and can be brought to the site. In addition, soil washing is relatively inexpensive ($120 to $200 per ton), but in many cases it is only a step toward reducing the volume of soil that requires additional treatment, such as when another technology is used to treat the reduced volume of contaminated soil following soil washing.

The operation and maintenance components of soil washing include preparing soils for treatment (moving soils, screening debris from soils), treating washing agents and soil fines following treatment, and returning clean soils to the site. The time required for treating a 20,000-ton site using soil washing would likely be less than 3 months.[85]

5.3.3 Wet Air Oxidation

Wet air oxidation (WAO) is a high-temperature, high-pressure oxidation process that can be used to treat contaminated soil. Contaminated slurries are pumped into a heat exchanger and heated to temperatures of 650-1,150 °F. The slurries are then pumped into a reactor where they are oxidized in an aqueous solution at pressures of 1,000 to 1,800 psi.

WAO has been proven to be highly effective in treating RDX. However, the method also produces hazardous byproducts of TNT and gaseous effluents that require additional treatment. The technology has high capital costs and a high level of downtime resulting from frequent blockages of the pump system and heat exchange lines. Laboratory tests have indicated that some WAO effluents can be further treated using biological methods such as composting.[86]

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[85]Ibid.

[86]J. Stratta, R. Schneider, N. Adrian, R. Weber, B. Donahue. *Alternatives to Open Burning/Open Detonation of Energetic Materials: A Summary of Current Technologies*. USACERL Technical Report 98/104, 1998.

5.3.4 Low-Temperature Thermal Desorption

Low-temperature thermal desorption (LTTD) is a commercially available physical separation process that heats contaminated soils to volatilize contaminants. The volatilized contaminants are then transported for treatment. While this system has been tested extensively for use on reactive and/or ignitable materials, it is not one of the more effective technologies. In general, a carrier gas or vacuum system transports volatilized water and reactive and/or ignitable materials to a gas treatment system such as an afterburner or activated carbon. The relatively low temperatures (200-600 EF) and residence times in LTTD typically volatilize low levels of reactive and/or ignitable materials and allow decontaminated soil to retain its physical properties.[87] In general, LTTD is used to treat volatile organic compounds and fuels, but it can potentially be used on soil containing low concentrations of reactive and/or ignitable materials that have boiling points within the LTTD temperature range (e.g., TNT).

The two commonly used LTTD systems are the rotary dryer and the thermal screw. Rotary dryers are horizontal cylinders that are inclined and rotated. In thermal screw units, screw conveyors or hollow augers are used to transport the soil or debris through an enclosed trough. Hot oil or steam circulates through the augur to indirectly heat the soil. The off-gas is treated using devices such as wet scrubbers or fabric filters to remove particulates, and combustion or oxidation is employed to destroy the contaminants.[88] The primary limitations of LTTD include the following:

- It is only marginally effective for treating reactive and/or ignitable materials.
- Extensive safety precautions must be taken to prevent explosions when exposing contaminated soil and debris to heat.
- Explosives concentration and particle size can affect the applicability and cost of LTTD.
- Plastic materials should not be treated using LTTD, as their decomposition products could damage the system.
- Soil with a high clay and silt content or with a high humic content will increase the residence time required for effective treatment.
- Soil or sediments with a high moisture content may require dewatering prior to treatment.
- Air pollution control devices are often necessary.
- Additional leaching of metals is a concern with this process.

5.4 Decontamination of Equipment and Scrap

Decontamination of equipment and scrap is essential in order to ensure that explosive residues no longer remain on the material. Attention to this process can significantly decrease safety hazards to workers and the public. Several instances of improperly treated range scrap sent to scrap yards for recycling have resulted in deaths in association with unplanned explosions. Various chemical and mechanical methods are available for the cleaning and decontamination of equipment and scrap metal. One such method is hot gas decontamination. Demonstrations have shown that a 99.9999 percent decontamination of structural components is possible using this method. Residue from

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[87] DoD Environmental Technology Transfer Committee. *Remediation Technologies Screening Matrix and Reference Guide*, Second Edition, October 1994.

[88] EPA Superfund Innovative Technology Evaluation (SITE) Program, Thermal Desorption System (TDS), Clean Berkshires, Inc., October 1999.

reactive and/or ignitable compounds is volatilized or decomposed during the process when gas is heated to 600 EF for 1 hour. Any off-gases are destroyed in a thermal oxidizer, and emissions are monitored to ensure compliance with requirements. Specifications state that the furnace can accept a maximum of 3,000 pounds of contaminated materials containing less than 1 pound of total explosives. Up to four batch runs can be processed by a two-person crew every 24 hours.[89]

Base hydrolysis is a chemical method of decontaminating material of reactive and/or ignitable compounds. A tank of heated sodium hydroxide is prepared at a concentration of 3 moles per liter. The high pH and high temperature have the effect of breaking apart any reactive and/or ignitable compounds on the scrap metal. Following decontamination, hydrochloric acid is added to lower the pH to a range of 6 to 9. The cleaned material has no detectable level of reactive and/or ignitable contaminants following the procedure. This process is scalable to accommodate a variable throughput.[90,91,92] Other decontamination methods include pressure washing, steam cleaning, and incineration.

5.5 Safe Deactivation of Energetic Materials and Beneficial Use of Byproducts

A technique for safely eliminating energetic materials and developing safe and useful byproducts is currently under development with funding from the Strategic Environmental Research and Development Program (SERDP). One such process reacts energetic materials, specifically TNT, RDX, and Composition B, with organic amines, which neutralize the energetic materials. The reaction is conducted at low temperatures, safely breaking down the energetic materials without causing detonation.

The gaseous byproducts of this process consist of nitrous oxide, nitrogen, water, and carbon dioxide. The liquid byproducts contain amide groups and carbon-nitrogen bonds. The liquid byproducts of TNT and RDX were discovered to be effective curing agents for conventional epoxy resins. The epoxy polymers produced using the curing agents derived from the liquid byproducts were subjected to safety and structural tests. It was determined that they have comparable mechanical properties to epoxy formed using conventional resins and curing agents. Testing is currently underway to verify their safety and resistance to leaching of toxic compounds.

In preliminary testing, this process has been shown to be a viable alternative to OB/OD and appears to have the potential to achieve high throughput, be cost-effective and safe, and discharge no toxic chemicals into the environment.[93]

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[89] U.S. Army Environmental Center. *Hot-Gas Decontamination: Proven Technology Transferred for Army Site Cleanups*, December 2000.

[90] UXB International, Inc. *UXBase: Non-Thermal Destruction of Propellant and Explosive Residues on Ordnance and Explosive Scrap*, 2001.

[91] D.R. Felt, S.L. Larson, and L.D. Hansen. *Kinetics of Base-Catalyzed 2,4,6-Trinitrotoluene Transformation*, August 2001.

[92] R.L. Bishop et al. "Base Hydrolysis of HMX and HMX-Based Plastic Bonded Explosives with Sodium Hydroxide between 100 and 155EC." Ind. Eng. Chem. Res. 1999, 38:2254-2259.

[93] SERDP and ESTCP. "Safe Deactivation of Energetic Materials and Beneficial Use of By-Products," Partners in Environmental Technology Newsletter, Issue 2, 1999.

5.6 Conclusion

The treatment of MEC and reactive and/or ignitable soil and debris is a complex issue in terms of technical capabilities, regulatory requirements, and environmental, public health, and safety considerations. Public concern over OB/OD and incineration has encouraged the development of new technologies to treat reactive and/or ignitable wastes, but there is still a long way to go before some of the newer technologies, such as plasma arc destruction, become commercially available and widely used. Further, many of the newer technologies have been developed for industrial facilities with high throughput levels usually not found at MRS. However, with the appropriate site-specific conditions, alternative technologies may be considered for munitions responses.

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

Stratta, J., R. Schneider, N. Adrian, R. Weber, and B. Donahue. ***Alternatives to Open Burning/Open Detonation of Energetic Materials: A Summary of Current Technologies***. U.S. Army Corps of Engineers, Construction Engineering Research Laboratories, Aug. 1998.

U.S. Department of Defense, Environmental Technology Transfer Committee. ***Remediation Technologies Screening Matrix***. 2d ed., Oct. 1994.

U.S. Environmental Protection Agency. ***Handbook: Approaches for the Remediation of Federal Facility Sites Contaminated with Explosive or Radioactive Wastes***. EPA/625/R-93/013, Sept. 1993.

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. ***Completed North American Innovative Remediation Technology Demonstration Projects***. NTIS No. PB96-153127; Aug. 1996.

Information Sources

Center for Public Environmental Oversight
c/o PSC 222B View Street
Mountain View, CA 94041
Tel: (650) 961-8918
Fax: (650) 968-1126
http://www.cpeo.org

Environmental Security Technology Certification Program (ESTCP)
901 North Stuart Street, Suite 303
Arlington, VA 22203
Tel: (703) 696-2127
Fax: (703) 696-2114
http://www.estcp.org

Federal Remediation Technologies Roundtable
U.S. EPA, Chair
(5102G) 401 M Street, S.W.
Washington, DC 20460
http://www.frtr.gov

Joint UXO Coordination Office (JUXOCO)
10221 Burbeck Road, Suite 430
Fort Belvoir, VA 22060
Tel: (703) 704-1090
Fax: (703) 704-2074
http://www.denix.osd.mil/UXOCOE

Naval Explosive Ordnance Disposal Technology Division
(NAVEODTECHDIV)
UXO Countermeasures Department, Code 30U
2008 Stump Neck Road
Indian Head, MD 20640-5070
http://www.ih.navy.mil/

Strategic Environmental Research and Development Program (SERDP)
901 North Stuart Street, Suite 303
Arlington, VA 22203
Tel: (703) 696-2117
http://www.serdp.org

U.S. Army Corps of Engineers
U.S. Army Engineering and Support Center,
Ordnance and Explosives Mandatory Center of Expertise
P.O. Box 1600
4820 University Square
Huntsville, AL 35807-4301
http://www.hnd.usace.army.mil/

U.S. Army Environmental Center (USAEC)
Aberdeen Proving Ground, MD 21010-5401
Tel: (800) USA-3845
http://aec.army.mil

U.S. Environmental Protection Agency, Office of Research and Development
Alternative Treatment Technology Information Center (**ATTIC**)
(a database of innovative treatment technologies)
http://www.epa.gov/bbsnrmrl/attic/index.html

U.S. EPA, Technology Information Office
Remediation and Characterization Innovative Technologies (REACH-IT)
http://www.epareachit.org/index.html

U.S. EPA, Technology Information Office
Hazardous Waste Clean-Up Information (CLU-IN)
http://www.clu-in.org/

Guidance

U.S. EPA, Office of Solid Waste and Emergency Response. ***Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, Underground Storage Tank Sites***. Directive 9200.4-17P; Apr. 21, 1999.

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6.0 EXPLOSIVES SAFETY

Substantial safety issues are associated with investigation and munition response activities at sites that may contain MEC. This section describes the statutory and regulatory requirements on explosives safety, as well as common practices for managing explosives safety. General safety practices are addressed, as are the specific requirements for the health and safety of munitions response personnel, explosive ordnance disposal (EOD) personnel, and protection of the public.

6.1 Introduction to DoD Explosives Safety Requirements and the DoD Explosives Safety Board (DDESB)

Explosives safety is overseen within the DoD by the DoD Explosives Safety Board (DDESB). This centralized DoD organization is charged with setting and overseeing explosives safety requirements throughout DoD (see text box on next page). DoD Directive 6055.9 (DoD Explosives Safety Board and DoD Component Explosives Safety Responsibilities) authorized the DoD Ammunition and Explosives Safety Standards (July 1999, 6055.9-STD). This directive requires the implementation and maintenance of an "aggressive" explosives safety program that addresses environmental considerations and requires the military components to act jointly.

Revision of Safety Standards

The 6055.9-STD is currently under revision by the DDESB. The revised standards are posted on the DDESB website as soon as they are voted in by the board (www.ddesb.pentagon.mil). Revisions of the standard dated October 2004 have been published on the DDESB website, and its use is mandated by DDESB. Several important revisions, however, including changes to Chapter 12 and a chapter on UXO, have not yet been completed or posted. This chapter of the handbook will be revised when the revision of the standards are complete.

The policies of DoD 6055.9-STD (the DoD explosives safety standard) include the following:

- Provide the maximum possible protection to personnel and property, both inside and outside the installation, from the damaging effects of potential accidents involving DoD ammunition and explosives.
- Limit the exposure to a minimum number of persons, for a minimum time, to the minimum amount of ammunition and explosives consistent with safe and efficient operations.

These policies apply to MEC contaminated property currently owned by DoD, property undergoing realignment or closure, and Formerly Used Defense Sites (FUDS), and require that every means possible be used to protect the public from exposure to explosive hazards. Property known to be or suspected of being contaminated with MEC must be decontaminated with the most appropriate technology to ensure protection of the public, taking into consideration the proposed end use of the property and the capabilities and limitations of the most current MEC detection and discrimination technologies.

The Role of the DoD Explosives Safety Board

The DDESB was established by Congress in 1928 as a result of a major disaster at the Naval Ammunition Depot in Lake Denmark, New Jersey, in 1926. The accident caused heavy damage to the depot and surrounding areas and communities, killed 21 people, and seriously injured 51 others.

The mission of the DDESB is to provide objective advice to the Secretary of Defense and Service Secretaries on matters concerning explosives safety and to prevent conditions that may be hazardous to life and property, both on and off DoD installations, that may result from explosives or the environmental effects of military munitions.

The roles and responsibilities of the DDESB were expanded in 1996 with the reissuance of DoD Directive 6055.9, on July 29, 1996. The directive gives the DDESB responsibility for resolving any potential conflicts between explosives safety standards and environmental standards.

To protect human health and property from hazards from explosives, the DDESB (or the organizations to which it delegates authority) has established requirements for overseeing all activities relating to munitions at property currently owned by DoD, property undergoing realignment or closure, and FUDS. As part of those responsibilities, the DDESB or its delegates must review and approve the explosives safety aspects of all plans for leasing, transferring, excessing, disposing of, or remediating DoD real property when MEC contamination exists or is suspected to exist. Plans to conduct munitions response actions at FUDS are also submitted to the DDESB for approval of the explosives safety aspects.[94] All explosives safety plans are to be documented in **Explosives Safety Submissions** (ESSs), which are submitted to DDESB for approval prior to any munitions response action being undertaken, or prior to any transfer of real property where MEC may be present (see Section 6.3.2 for a discussion on ESSs). Several investigation and documentation requirements must be fulfilled in order to complete an ESS (see Section 6.3.3).

The DoD explosives safety standard (6055.9-STD) also applies to any investigation (either intrusive or nonintrusive) of any ranges or other areas that are known or suspected to have MEC. Adherence to DoD safety standards and to the standards and requirements of the Occupational Safety and Health Administration (OSHA) is documented in approved, project-specific Site Safety and Health Plans (SSHPs) for investigations and cleanup actions.[95,96] The DDESB may review SSHPs if requested to do so, but approval of these plans is generally overseen by the individual component's explosives safety center. Elements of the SSHP and the ESS are likely to overlap, particularly when the SSHP addresses response actions.

The DoD explosives safety standard is a lengthy document with a great deal of technical detail. It is organized around 13 technical chapters[97], plus an introduction. These chapters address the following:

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[94]*DoD Ammunition and Explosives Safety Standards*, DoD Directive 6055.9-STD, Chapter 12, July 1999.

[95]Occupational Safety and Health Administration Standard, 29 C.F.R. § 1910.120 (b)(4), § 1926.65 (b)(4).

[96]National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. § 300.430 (b)(6).

[97]Chapter titles reflect changes in DoD's 6055.9-STD, rev. 5 dated June 2004.

- **Reaction effects —** as they relate to buildings, transportation, and personnel.
- **Hazard classification, storage principles, and compatibility groups** — to guide the kinds of explosives that may and may not be stored together.[98]
- **Personnel protection —** from blast, fragmentation, and thermal hazards.
- **Construction criteria permitting reduced separation distances —** as they apply to potential explosion sites.
- **Electrical standards** — establishing minimum requirements for DoD buildings and areas containing explosives.
- **Lightning protection** — for ammunition and explosives facilities, including safety criteria for the design, maintenance, testing, and inspection of lightning protection systems.
- **Hazard identification for fire fighting and emergency planning** — providing criteria to minimize risk in fighting fires involving ammunition and explosives.
- **Quantity-distance (Q-D) and siting** — minimum standards for separating a potential explosion site from an exposed site.
- **Contingencies, combat operations, military operations other than war (MOOTW) and associated training** — setting standards outside the continental United States and inside the United States in certain CONUS training situations where the premise "to train as we fight" would be compromised.
- **Toxic chemical munitions and agents** — for protecting workers and the general public from the harmful effects of chemical agents.
- **Real property contaminated with ammunition, explosives, or chemical agents** — establishing the policies and procedures necessary to protect personnel exposed "as a result of DoD ammunition, explosives, or chemical agent contamination of real property currently and formerly owned, leased, or used by the Department of Defense."
- **Accident notification and reporting requirements** — establishing procedures and data to be reported for all munition and explosive mishaps.
- **Special storage procedures for waste military munitions** — under a conditional exemption from certain RCRA requirements or a new RCRA storage unit standard, as set forth in the Military Munitions Rule (40 C.F.R 260) *Federal Register* 62(29): 6621-6657 (February 12, 1997)

6.2 Explosives Safety Requirements

Safety standards published by DDESB are to be considered minimum protection criteria. In addition to 6055.9-STD, explosives safety organizations are in place in each of the military components. Each has established its own procedures. A number of these centers have developed additional technical guidance. The following sections highlight key safety considerations as described in 6055.9-STD or in various other guidance documents published by military components. While they often contain similar requirements, guidance documents produced by different components may use different terminology.

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[98] Hazard classification procedures have been updated in *Changes to Department of Defense Ammunition and Explosives Hazard Classification Procedures*, DDESB-KT, July 25, 2001.

6.2.1 General Safety Rules

The following commonsense safety rules apply to all munitions response actions and explosives ordnance disposal (EOD) activities:

> **Radio Frequencies**
>
> Some types of ordnance are susceptible to electro-magnetic radiation (EMR) devices in the radio frequency (RF) range (i.e., radio, radar, cellular phone, and television transmitters). Preventive steps should be taken if such ordnance is encountered in a suspected EMR/RF environment. The presence of antennas and communication and radar devices should be noted before initiating any ordnance-related activities. When potential EMR hazards exist, the site should be electronically surveyed for EMR/RF emissions and the appropriate

- Only **qualified UXO/EOD personnel** can be involved in munitions response actions. However, non-UXO-qualified personnel may be used to perform UXO-related procedures when supervised by UXO-qualified personnel. All personnel must be trained in explosives safety and be capable of recognizing hazardous situations.
- An **exclusion zone** (a safety zone established around an MEC work area) must be established. Only essential project personnel and authorized, escorted visitors are allowed within the exclusion zone. Essential personnel are those who are needed for the operations being performed. Unauthorized personnel must not be permitted to enter the area of activity.
- **Warning signs** must be posted to warn the public to stay off the site.
- **Proper supervision** of the operation must be provided.
- **Personnel are not allowed to work alone** during operations.
- **Exposure should be limited** to the minimum number of personnel needed for a minimum period of time.
- Appropriate use of **protective barriers** or distance separation must be enforced.
- **Personnel must not be allowed to become careless** by reason of familiarity with munitions.

6.2.2 Transportation and Storage Requirements

The DoD explosives safety standard requires that explosives be stored and transported with the highest possible level of safety. The standard calls for implementation of the international system of classification developed by the United Nations Committee of Experts for the Transport of Dangerous Goods and the hazardous material transportation requirements of the U.S. Department of Transportation. The classification system comprises nine hazard classes, two of which are applicable to munitions and explosives. Guidelines are also provided for segregating munitions and explosives into compatibility groups that have similar characteristics, properties, and potential accident effects so that they can be transported together without increasing significantly either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident.

The DoD Ammunition and Explosives Hazard Classification Procedures calls for the following safety precautions for transporting conventional UXO in a nonemergency response:[99]

[99] *Changes to Department of Defense Ammunition and Explosives Hazard Classification Procedures*, DDESB-KT, July 25, 2001.

- C EOD-qualified personnel must evaluate the UXO and affirm in writing that the item is safe for transport prior to transport from the installation or FUDS.
- C UXO should be transported in a military vehicle using military personnel where possible. For FUDS, such transport, when it occurs, will be by UXO personnel in accordance with the work plan.[100]
- C All UXO shall be transported and stored as hazard class 1.1 (defined as UXO capable of mass explosion) and with the appropriate compatibility group. UXO shall be stored separately from serviceable munitions.[101]
- C Military components, working with EOD units, will determine the appropriate packaging, blocking and bracing, marking, and labeling, and any special handling requirements for transporting UXO over public transportation routes.

Similarly, storage principles require that munitions and explosives be assigned to compatibility groups, munitions that can be stored together without increasing the likelihood of an accident or increasing the magnitude of the effects of an accident. The considerations used to develop these compatibility groups include chemical and physical properties, design characteristics, inner and outer packing configurations, Q-D classification, net explosive weight, rate of deterioration, sensitivity to initiation, and effects of deflagration, explosion, or detonation.

6.2.3 Quantity-Distance (Q-D) Requirements

The DoD explosives safety standard establishes guidelines for maintaining separation between the explosive material expected to be encountered in the response action and potential receptors such as personnel, buildings, explosive storage magazines, and public traffic routes. These encounters may be planned encounters (e.g., open burning/open detonation) or accidental (e.g., contact with an ordnance item during investigation). The standard provides formulas for estimating the damage or injury potential based on the nature and quantity of the explosives, and the minimum separation distance from receptors at which explosives would not cause damage or injury.

These Q-D siting requirements must be met in the ESS for all munitions response actions, for storage magazines used to store demolition explosives and recovered MEC, and for planned or established demolition areas. In addition, "footprint" areas, those in which render-safe or blow-in-place procedures will occur during the response action, are also subject to Q-D siting requirements, but they are not included in the ESS because they are determined during the actual removal process.

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[100]Written comment from U.S. Army.

[101]For the sake of convenience, the term *munition* has been used throughout this chapter, in some cases where the source used the term *ammunition*.

Examples of Quantity-Distance Siting Requirements

The following are examples of key concepts used in establishing Q-D requirements (USACE Engineering Manual 1110-1-4009, June 2000):

- Extensive and well-documented historical information is essential to understanding the blast and damage potential at a given MRS.
- For all MRSs, a most probable munition (MPM) is determined on the basis of munitions items anticipated to be found at the site. The MPM is the item that has the greatest hazard distance (the maximum range fragments and debris will be thrown), based on calculations of explosive effects. The two key elements considered in establishing the hazard distance for the MPM are fragmentation (the breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place) and overpressure (the blast wave or sudden pressure increase).
- For explosive soils, a different concept, called maximum credible event (MCE), applies. The MCE is calculated by relating the concentration of explosives in soil to the weight of the mix. Overpressure and soil ejection radius are considered in determining Q-D requirements for explosive soils.

6.2.4 Protective Measures for UXO/EOD Personnel

The DoD safety standard and CERCLA, OSHA, and component guidance documents require that protective measures be taken to protect personnel during investigation and response actions. The DDESB and military components have established guidelines for implementing such measures. UXO/EOD personnel conducting MEC investigations and response actions face potential risk of injury and death during these activities. Therefore, in addition to general precautions, DoD health and safety requirements include (but are not limited to) medical surveillance and proper training of personnel, as well as the preparation and implementation of emergency response and personal protective equipment (PPE) programs.

6.2.5 Emergency Response and Contingency Procedures

In the event that an MEC incident occurs during response actions or disposal, injuries can be limited by maintaining a high degree of organization and preparedness. CERCLA, OSHA, and military component regulations call for the development and implementation of emergency response procedures before any ordnance-related activities take place. The minimum elements of an emergency response plan include the following:

- Ensure availability of a nearby qualified emergency medical technician (EMT) with a first-aid kit.
- Ensure that communication lines and transportation (i.e., a designated vehicle) are readily available to effectively care for injured personnel.
- Maintain drenching and/or flushing facilities in the area for immediate use in the event of contact with toxic or corrosive materials.
- Develop procedures for reporting incidents to appropriate authorities.
- Determine personnel roles, lines of authority, and communications procedures.
- Post emergency instructions and a list of emergency contacts.
- Train personnel in emergency recognition and prevention.
- Establish the criteria and procedures for site evacuation (emergency alerting procedures, place of refuge, evacuation routes, site security, and control).

- Plan specific procedures for decontamination and medical treatment of injured personnel.
- Have route maps to nearest prenotified medical facility readily available.
- Establish the criteria for initiating a community alert program, contacts, and responsibilities.
- Critique the emergency responses and follow-up activities after each incident.
- Develop procedures for the safe transport and/or disposal of any live MEC items. In addition, handle practice rounds with extreme caution and use chain-of-custody procedures similar to those for live UXO items (practice rounds may contain explosive charges).
- Plan the procedures for acquisition, transport, and storage following demolition of recovered UXO items.

Equipment such as first-aid supplies, fire extinguishers, a designated emergency vehicle, and emergency eyewashes/showers should be immediately available in the event of an emergency.

6.2.6 Personnel Protective Equipment (PPE)

As required by CERCLA, OSHA, and military component regulations, a PPE program should be in place for all munitions response actions. Prior to initiating any ordnance-related activity, a hazard assessment should be performed to select the appropriate equipment, shielding, engineering controls, and protective clothing to best protect personnel. Examples of PPE include flame-resistant clothing and eye and face protection equipment. A PPE plan is also highly recommended to ensure proper selection, use, and maintenance of PPE. The plan should address the following activities:

- PPE selection based on site-specific hazards
- Use and limitations of PPE
- Maintenance and storage of PPE
- Decontamination and disposal of PPE
- PPE training and fitting
- Equipment donning and removal procedures
- Procedures for inspecting equipment before, during, and after use
- Evaluation of the effectiveness of the PPE plan
- Medical considerations (e.g., work limitations due to temperature extremes)

6.2.7 Personnel Standards

Personnel standards are designed to ensure that the personnel working on or overseeing the site are appropriately trained. Typical requirements for personnel training vary by level and type of responsibility, but will specify graduation from one of DoD's training programs. USACE, for example, requires that all military and contractor personnel be graduates of one of the following schools or courses:

- The U.S. Army Bomb Disposal School, Aberdeen Proving Ground, Maryland
- U.S. Naval Explosive Ordnance Disposal School, Eglin Air Force Base, Florida (or Indian Head, Maryland, prior to spring 1999)
- The EOD Assistant's Course, Redstone Arsenal, Alabama
- The EOD Assistant's Course, Eglin Air Force Base, Florida
- Other DoD-certified course

USACE specifically requires that UXO safety officers be graduates of the Army Bomb Disposal School and/or the Naval EOD School and have at least 10 years of experience in all phases of UXO remediation and applicable safety standards. Senior UXO supervisors must be graduates of the same programs and have had at least 15 years of experience in all aspects of UXO remediation and at least 5 years of experience in a supervisory capacity.[102]

6.2.8 Assessment Depths

In addition to safeguarding UXO personnel from the hazards from explosives, the DoD explosives safety standard also mandates protecting the public from MEC hazards. Even at a site that is thought to be fully remediated, there is no way to know with certainty that every MEC item has been removed. Therefore, the public must be protected from MEC even after a munitions response action has been completed. The types and levels of public safeguards will vary with the level of uncertainty and risk at a site. Public safeguards include property clearance (e.g., depth of response) to the appropriate depth for planned land uses and enforcement of designated land uses.

ESS approvals rely on the development of site-specific information to determine response depth requirements. The response depth selected for response actions is determined using site-specific information such as the following:

- Geophysical characteristics such as bedrock depth and frost line (see Chapters 3 and 7 and text box on the next page).
- Estimated MEC depth based on surface detection and intrusive sampling.
- In the absence of sampling data, information about the maximum depth of ordnance used on-site based on maximum penetration source documents.
- Actual planned land use that may require deeper excavation than the default clearance depths (e.g., a commercial or industrial building with foundations deeper than 10 feet).
- Remediation response depth a minimum of 4 feet below the excavation depth planned for construction (DDESB requirement).
- Presence of cultural or natural resources (e.g., potential risk to soil biota or archeologically sensitive areas)

EPA/DoD Management Principles on Standards for Depths of Clearance

- In the absence of site-specific data, a table of assessment depths is used for interim planning purposes until the site-specific information is developed.
- Site-specific data are necessary to determine the actual depth of clearance.

Other factors that affect the munitions response depth include the size of the range, the cost of the munition response (depends on many variables, including range size and terrain), and the practicality of finding and excavating all of the MEC. [103]

[102] *Ordnance and Explosives Response: Engineering and Design*, U.S. Army Corps of Engineers, EP 1110-1-18, April 24, 2000.

[103] Attachment 1 at the conclusion of this chapter contains a table that has historically been part of the DDESB standard in Chapter 12. This table provided assessment depths to be used for planning purposes when site-specific information is not available. It is provided to the reader for historical reference.

If MEC detection capabilities are not sensitive enough or funds are not available to remove MEC to the depth needed to meet site specific response requirements, then the proposed land use must be changed so that risks to human health and the environment are managed appropriately. Site records should include information concerning the depth to which MEC was removed, the process by which that depth was determined, and notice of the risks to safety if the end land use is violated.

> **Frost Line and Erosion**
>
> The ultimate removal depth must consider the frost line of the site and the potential for erosion. A phenomenon known as **frost heave** can move ordnance to the surface during the freeze and thaw cycles. If ordnance is not cleared to the frost line depth, or if the site conditions indicate erosion potential (such as in agricultural areas), a procedure must be put in place to monitor the site for migration of ordnance. (See Chapter 3, Section 3.3.3, for more information on this topic.)

6.2.9 Land Use Controls

Land use controls include institutional controls (e.g., legal or governmental), site access (e.g., fences), and engineering controls (e.g., caps over contaminated areas) that separate people from potential hazards. They are designed to reduce ordnance and explosive risk over the long term without physically removing all of the MEC. Land use controls are necessary at many sites because of the technical limitations and prohibitive costs of adequately conducting munitions responses to allow for certain end uses, particularly unrestricted use (see text box).

> **Examples of Land Use Controls**
>
> - Security fencing or other measures to limit access
> - Warning signs
> - Postremoval site control (maintenance and surveillance)
> - Land repurchase
> - Deed restrictions

The DoD explosives safety standard specifically addresses a requirement for institutional controls when MEC contamination has been or may still be on the site: "Property transfer records shall detail past munition and explosive contamination and decontamination efforts; provide requisite residual contamination information; and advise the user not to excavate or drill in a residual contamination area without a metal detection survey."[104]

The appropriate land use control depends on site-specific factors such as proximity to populations, land use, risk of encountering MEC, community involvement, and site ownership (both current and future). It is important to coordinate activities with the appropriate Federal, State, local, and Tribal governments in the development and implementation of land use controls to ensure their effectiveness even after the response action has been completed (see text box on next page).

The EPA policy "Institutional Controls and Transfer of Real Property under CERCLA Section 120 (h)(3)(A), (B), or (C)" recognizes that although a variety of land use controls may be used to manage risk at sites, the maintenance of site access and engineering controls depends on institutional controls. Institutional controls include the governmental and legal management controls that help ensure that engineering and site access controls are maintained. The Federal agency in charge of a site has responsibilities beyond implementing the institutional controls. EPA policy requires the

[104]Department of Defense. *DoD Ammunition and Explosives Safety Standard*, DoD 6055.9-STD, July 1999.

responsible agency to perform the following activities:[105]

- **Monitor** the institutional controls' effectiveness and integrity.
- **Report** the results of such monitoring, including notice of violation or failure of controls, to the appropriate EPA and/or State regulator, local or Tribal government, and designated party or entity responsible for enforcement.
- **Enforce** the institutional controls should a violation or failure of the controls occur.

In order to ensure long-term protection of human health and safety in the presence of potential explosive hazards, institutional controls must be enforceable against whomever may gain ownership or control of the property in the future.

EPA/DoD Interim Final Management Principles on Land Use Controls

- Land use controls must be clearly defined, established in coordination with affected parties, and enforceable.
- Land use controls will be considered as part of the development and evaluation of response alternatives for a given munitions response.
- DoD will conduct periodic reviews to ensure the long-term effectiveness of response actions, including land use controls.

6.3 Managing Explosives Safety

DoD Directive 6055.9 establishes the roles and responsibilities for DDESB and each of the military components. DDESB oversees implementation of safety standards throughout DoD and may conduct surveys to identify whether such standards are appropriately implemented. The military components conduct similar reviews within their respective services. At ranges where investigation, response action, and real property transfer are the major focus, the implementation of explosives safety requirements is normally documented in two ways:

- **Site Safety and Health Plans (SSHPs)** describe activities to be taken to comply with occupational health and safety regulations. SSHPs are often part of a work plan for investigation and response. Approval of specific SSHPs is typically conducted by the individual military component responsible for the response action (e.g., Army, Navy, or Air Force) through their explosives safety organizations. SSHPs and other components of the work plan are used to incorporate the requirements of 6055.9-STD into investigation plans. They are not reviewed individually by DDESB.
- **Explosives Safety Submissions (ESSs)** describe the safety considerations of the planned response actions, including the impact of planned clearance depths on current and future land use. All DoD ESSs are submitted to and approved by DDESB, as described in Sections 6.3.2 and 6.3.3.

  Many requirements documented in detail in the SSHP are summarized in the ESS.

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[105]U.S. EPA. *Institutional Controls and Transfer of Real Property Under CERCLA Section 120 (h)(3)(A), (B), or (C)*, Interim Final Guidance, January 2000.

- **Explosive Safety Plans (ESPs)** describe safety considerations associated with anomaly disposal, treatment, and storage during investigations. DDESB approval of such plans is required when locations used for such activities are permanent (more than 12 months) or recurring.[106]

6.3.1 Site Safety and Health Plans

SSHPs fulfill detailed requirements for compliance with the occupational safety and health program requirements of CERCLA, OSHA, and the military components.[107,108,109] SSHPs are based on the premise of limiting the exposure to the minimum amount of MEC and to the fewest personnel for the shortest possible period of time. Prior to the initiation of on-site investigations, or any design, construction, or operation and maintenance activities, an SSHP must be prepared and submitted for review and acceptance for each site task and operation described in the work plan.[110] SSHPs are typically prepared by industrial hygiene personnel at the installation level.[111] The SSHP review and approval processes vary with the type of property (e.g., FUDS, BRAC, active installations), the stage of the investigation, and the military component responsible. Typically, however, the component's safety organization will be responsible for the review and approval of SSHPs (see text box on next page).

The SSHP describes the safety and health procedures, practices, and equipment to be used to protect personnel from the MEC hazards of each phase of the site activity. The level of detail to be included in the SSHP should reflect the requirements of the site-specific project, including the level of complexity and anticipated hazards. Nonintrusive investigation activities such as site visits or pre-work-plan visits may require abbreviated SSHPs.[112] Specific elements to be addressed in the SSHP include several of those discussed in previous sections, including:

- Personnel protective equipment,
- Emergency response and contingency planning, and
- Employee training.

Other commonly required elements of SSHPs include, but are not limited to:

- Employee medical surveillance programs;
- Frequency and type of air monitoring, personnel monitoring, and environmental

[106]Department of Defense. *DoD Ammunition and Explosives Safety Standard*, Chapter 10, DoD 6055.9-STD, October 2004.

[107]National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. § 300.430 (b)(6).

[108]Occupational Safety and Health Administration Standard, 29 C.F.R. § 1910.120 (b)(4), § 1926.65 (b)(4).

[109]*Ordnance and Explosives Response: Engineering and Design*, U.S. Army Corps of Engineers, EP 1110-1-18, April 24, 2000.

[110]*Safety and Health Requirements*, U.S. Army Corps of Engineers, EM 385-1-1, September 3, 1996.

[111]*Safety and Occupational Health Requirements for Hazardous, Toxic, and Radioactive Waste (HTRW) Activities*, ER 385-1-92, September 1, 2000.

[112]*Ordnance and Explosives Response: Engineering and Design*, U.S. Army Corps of Engineers, EP 1110-1-18, April 24, 2000.

sampling techniques and instrumentation to be used;
- Site control measures to limit access; and
- Documented standard operating procedures for investigating or remediating MEC.

Implementation of Explosives Safety at the Site Level

Each military component has its own set of specific requirements for work plans and Site Safety and Health Plans (SSHPs). The nomenclature and organization may vary by component. USACE requires the following plans in the implementation of explosives safety requirements. These will not necessarily be separate plans, but may be subplans of response action work plans.

- **Explosives Management Plan**, regarding the procedures and materials that will be used to manage explosives at the site, including acquisition, receipt, storage, transportation, and inventory.
- **Explosives Siting Plan**, providing the safety criteria for siting explosives operations at the site. This plan should provide a description of explosives, storage magazines, including the net explosive weight (NEW) and quantity-distance (Q-D) criteria, and MRSs, including separation distances and demolition areas, all of which should be identified on a site map. The footprint of all areas handling explosives also should be identified. Explosives siting plans should be incorporated into the Q-D section of the ESS.
- **Site Safety and Health Plan (SSHP)**, addressing the safety and health hazards of each phase of site activity and the procedures for their control. The SSHP includes, but is not limited to, the following elements:
  - Safety and health risk or hazard analysis for each site task identified in the work plan
  - Employee training assignments
  - Personal protective equipment program
  - Medical surveillance requirements
  - Frequency and type of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used
  - Emergency response plan
  - Site control program

Sources: Engineering and Design of Ordnance and Explosives Response, U.S. Army Corps of Engineers, EM 1110-1-4009, June 23, 2000; and Safety and Health Requirements Manual, U.S. Army Corps of Engineers, EM-385-1-1, September 3, 1996.

6.3.2 Explosives Safety Submissions for Munitions Response Actions

An Explosives Safety Submission (ESS) must be completed by those wishing to conduct an MEC investigation and response action and approved by appropriate authorities prior to commencing work (see text box at right). Although the DDESB oversees the approval process, the internal approval processes are slightly different for each military component. However, all ESSs should be written in coordination with the DDESB, as well as with stakeholder, public, and Tribal participation. In addition, the DDESB's role in approving ESSs is slightly different, depending on whether it is related to a FUDS project, a BRAC-related project involving property disposal, or a project at an active facility:

EPA/DoD Interim Final Management Principles on Explosives Safety Submissions

Explosives Safety Submissions (ESS), prepared, submitted, and approved per DDESB requirements, are required for time-critical removal actions, non-time-critical removal actions, and remedial actions involving explosives safety hazards, particularly UXO.

- For all DoD-owned facilities, the ESS is prepared at the installation level (either the active installation or the BRAC facility) and sent through the designated explosives safety office for initial approval. The role of the explosives safety organization in the approval chain differs slightly by component.

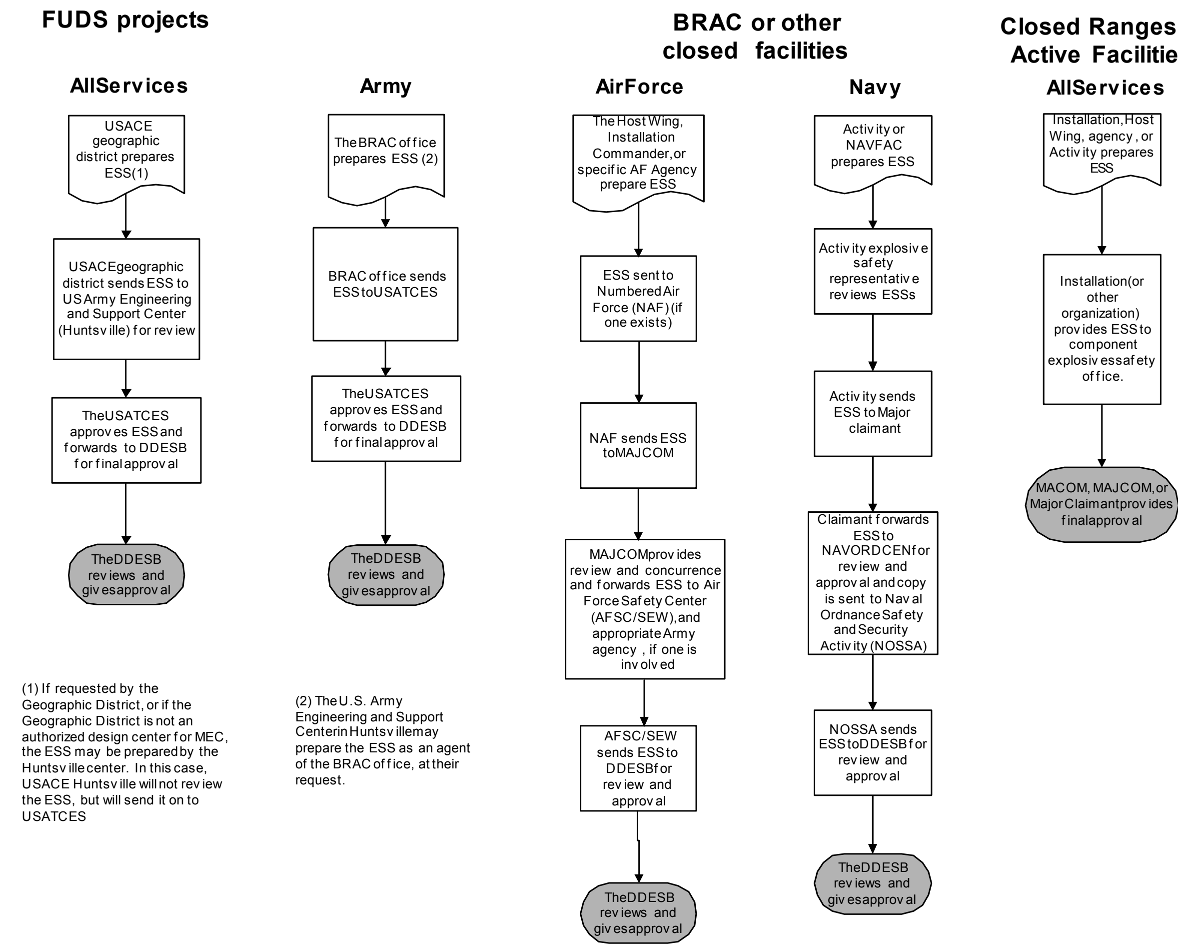
- For FUDS, the initial ESS is prepared by the USACE district with responsibility for the site.
- The DDESB reviews and gives approval to all ESSs at BRAC facilities and other closed facilities (i.e., a facility that has been closed by a component but is not part of the BRAC program).
- Final approval of ESSs for closed ranges at active facilities is provided by the command (e.g., MAJCOM, MACOM, or Major Claimant) often in coordination with the DDESB.

Coordination Prior to Submission of the ESS

ESSs, reviewed by the DDESB, must include a description of public and regulator involvement in the selection of the response before they are approved. The extent to which involved parties agree with the proposed response action is important to avoiding unnecessary conflict and delay of the proposed cleanup. This issue has received specific attention during development of the UXO Interim Final Management Principles.

Source: Interview with DDESB secretariat member.

An ESS is not required for military EOD emergency response actions (on DoD or non-DoD property); for interim removal actions taken to abate an immediate, extremely high hazard; and for normal maintenance operations conducted on active ranges. Figure 6-1 outlines the approval processes for MEC projects under different types of DoD ownership. “Sources and Resources,” at the end of this chapter, lists the location of the various explosives safety offices for each of the military components.



Sources: Personal communication with Clifford H. Doyle, Safety and Occupational Health Manager, USATACES, June 1, 2004
NAVSEA OP 5, Ammunition and Explosives Ashore: Safety Regulations for Handling, Storing, Production, Renovation and Shipping, Vol. 1, Rev. 6, Chg. 4.
Air Force Manual 91-201, Explosives Safety Standards, 7 March 2000

Figure 6-1. Routing and Approval of Explosives Safety Submission (ESS) for Munitions Response Actions

6.3.3 Explosives Safety Submission Requirements

Safety planning involves a thorough assessment of the explosive hazards likely to be encountered on-site during the investigation and response actions. The potential explosive hazards must be assessed and documented prior to submitting an explosives safety plan, as outlined in the next text box.[113]

[113] U.S. Army. *Explosives Safety Policy for Real Property Containing Conventional Ordnance and Explosives*, DACS-SF HQDA LTR 385-00-2, June 30, 2000.

Explosives Safety Submission Requirements

Safety plans are submitted at least 60 days prior to the planned response action and typically cover the following elements:

1. Reason for MEC presence
2. Maps (regional, site, quantity-distance, and soil sampling)
3. Amounts and types of MEC
4. Start date of removal action
5. Frost line depth and provisions for surveillance (if necessary)
6. Clearance techniques (to detect, recover, and destroy MEC)
7. Alternate techniques (to destroy MEC on-site if detonation is not used)
8. Q-D criteria (MRAs, magazines, demolition areas, "footprint" areas)
9. Off-site disposal (method and transportation precautions, if necessary)
10. Technical support
11. Land use restrictions and other institutional controls
12. Public involvement
13. After-action report (list MEC found by type, location, and depth)
14. Amendments and corrections to submission

The ESS often includes information obtained in preliminary studies, historical research, previous MEC sampling reports, and SSHPs. Specific information required in the submission includes the following:

- Quantity-distance (Q-D) maps describing the location of MEC, storage magazines, and demolition areas
- Soil sampling maps for explosives-contaminated soils
- The amounts and types of MEC expected based on historical research and site sampling
- Planned techniques to detect, recover, and destroy MEC[114]

The amount and type of MEC expected in each MRS is identified in the ESS. The submission must specify the most probable munition likely to be present. The most probable munition is the round with the greatest fragmentation distance that is anticipated to be found in any particular MRS. The ESS also identifies explosives-contaminated soils, which are expressed as the maximum credible event (established by multiplying the concentration of explosives times the weight of the explosives-contaminated soil). These data are input into formulas for establishing the damage or injury potential of the MEC on-site. See the text box in Section 6.2.3 on Q-D requirements for additional information about the use of these data in the ESS.

6.3.4 Explosives Safety Plans

An Explosive Safety Plan (ESP) is another document through which the components and DDESB implement the 6055.9-STD at ammunition and explosive locations. Such plans are required to be prepared with regard to the siting of locations used for the treatment or disposal of MEC (e.g., open burn or open detonation), prior to disposal. These plans must be approved by DDESB when

[114] *Explosives Safety Submissions for Removal of Ordnance and Explosives (OE) from Real Property*, Guidance for Clearance Plans, DDESB-KO, February 27, 1998.

they are either permanent locations (in use more than 12 months) or in recurrent use (periodic use, regardless of the duration of the operation). Plans for temporary operations or those for which advanced planning and approval is impracticable are approved by the applicable commander.[115]

General requirements for Explosive Safety Plans include, but are not limited to:

- Description of the use of the location;
- Maps;
- Quantity distance areas and all activities;
- Facilities and infrastructure potentially impacted by the location;
- Design procedures for engineering protections that DDESB has not already approved;
- Information on the type and arrangement of explosives operations or chemical processing equipment; and
- A topography map with contours.

When chemical agents are involved, a variety of specific information such as personnel protective clothing and equipment, wind direction and speed, warming and detection systems; and other requirements related to chemical safety.

6.4 Public Education About UXO Safety

Public education is an important component of managing explosive hazards and their potential impacts on human health and safety. At some sites, such as at Naval Air Station Adak in Alaska, it is technically and economically impossible to remove all of the MEC littered throughout the island. In such a situation, educating the public about hazards posed by MEC is a necessity in protecting the public. Also, at other, less contaminated sites where cleared areas are being opened to the public but where a small number of UXO items may remain, public education is also necessary in the event that someone encounters a previously undetected UXO item. A discussion of the highly successful public education program at NAS Adak is presented in the following text box.

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[115] Department of Defense. *DoD Ammunition and Explosives Safety Standard*, DoD 6055.9-STD, rev. 5, June 2004.

Adak Island, Alaska

The northern half of Adak Island was used by the Army Air Corps and then the Navy for over 50 years, resulting in UXO and MEC materials in and around the former range areas. Some portions of the property have been made suitable for transfer while others have been/are being retained by the Navy because of the presence of known ordnance. The parcels of land that are being transferred to local commercial interests may still contain isolated MEC in developed and undeveloped portions of the property. The Reuse Safety Plan stipulates permitted land use activities and regulatory, legal, and educational requirements to ensure the safety of residents (both current and future) and visitors to the island.

Historically, the U.S. Fish and Wildlife Service (USFWS), which now owns the land, implemented a comprehensive program to provide education about ordnance to visitors to Adak. This program, along with other institutional controls, has resulted in a very low number of ordnance-related injuries on Adak Island over the past 50 years.

The islandwide ordnance education program now includes several approaches:

- **Ordnance safety videos** are shown to new visitors or future residents before they are allowed to work or reside on the island. The videos cover the following topics:
  - Dig permit requirements
  - MEC identification
  - Safety requirements for construction personnel
  - Geophysical screening
  - Locations of UXO sites and clearance activities
  - Ordnance descriptions
  - Safety protocols
  - Access restrictions and warning signs
  - Emergency procedures
- An **ordnance education program** is incorporated into the educational system at the lower grades to educate and protect local children.
- The **Adak On-line Safety Program** was developed by the Navy to assist in the annual ordnance safety certification process for residents and visitors. The program includes a description of the types of ordnance hazards that may potentially exist, an automated dig permit application, an on-line graphic glossary of historical ordnance locations and schematics of the most commonly found ordnance types, emergency procedures, and a database to record the training records of everyone who has taken the on-line training.
- **Deed restrictions** ensure that future purchasers of property are aware of potential contamination on the property.
- **Signage** for restricted and nonrestricted property is posted at entrances and exits and at specified intervals along the perimeter.

Education about the hazards associated with MEC should be available to everyone in the community, with special attention paid to those who reside, work, and play at or near affected areas. Public education should be directed at both the adults and children of the community and should be reinforced on a regular basis. However, a balance must be found between addressing explosives safety and alarming the public. The types of information conveyed to the public should include the fact that any MEC item poses the risk of injury or death to anyone in the vicinity. MEC can be found anywhere – on the ground surface, or partially or fully buried. MEC can be found in any state – fully intact or in parts or fragments. An encounter with MEC should be reported immediately – either to site EOD personnel or, if they are not available, the military provost marshal or the local law enforcement agency.

Those living, working, or recreating in or near areas thought to contain MEC should be taught what to do and what not to do in the event of an encounter with MEC, including whom they should notify. The Navy EOD Technology Division has developed instructions for the public and site personnel to follow in the event of an encounter with MEC, as described in the following text box.

Instructions for Responding to and Reporting MEC Hazards

1. After identifying the potential presence of MEC, do not move any closer to it. Some types of ordnance have magnetic or motion-sensitive proximity fuzes that may detonate when they sense a target. Others may have self-destruct timers built in.
2. Do not transmit any radio frequencies in the vicinity of a suspected MEC hazard. Signals transmitted from items such as walkie-talkies, short-wave radios, citizens band (CB) radios, cellular phone, or other communication or navigation devices may detonate the MEC.
3. Do not attempt to remove any object on, attached to, or near a MEC. Some fuzes are motion-sensitive, and the MEC may explode.
4. Do not move or disturb a MEC because the motion could activate the fuze, causing the MEC to explode.
5. If possible, mark the MEC hazard site with a standard MEC marker or with other suitable materials, such as engineer's tape, colored cloth, or colored ribbon. Attach the marker to an object so that it is about 3 feet off the ground and visible from all approaches. Place the marker no closer than the point where you first recognized the MEC hazard.
6. Leave the MEC hazard area.
7. Report the MEC to the proper authorities.
8. Stay away from areas of known or suspected MEC. This is the best way to prevent accidental injury or death.

REMEMBER: "IF YOU DID NOT DROP IT, DO NOT PICK IT UP!"

6.5 Conclusion

DoD has developed extensive requirements aimed at protecting MEC workers and the public from explosive hazards. These safeguards include general precautions as well as highly technical explosives safety and personnel health and safety requirements. Management requirements include preparing and submitting SSHPs for all MEC investigations and response actions, and ESSs for munitions removal actions. SSHPs require that protective measures be taken for MEC personnel, including the development and implementation of emergency response and contingency plans, personnel training, medical surveillance, and personnel protective equipment programs. The development of ESSs requires knowledge about the munitions likely to be found on-site and the devising of plans for separating explosive hazards from potential receptors.

DoD safety guidance also addresses the protection of public health and safety. The DoD explosives safety standard (6055.9-STD) provides assessment depths to be used for planning purposes, storage and transport principles, and land use controls, all of which are designed to ensure long-term protection of human health and safety.

Public health and safety can also be protected by educating the public about explosives safety. In addition, educating the public about procedures to follow upon encountering MEC will help to prevent accidents and to give the public control over protecting themselves from explosive hazards.

ATTACHMENT 6.1

ASSESSMENT DEPTHS TO BE USED FOR PLANNING PURPOSES

Planned Land Use	Depth
Unrestricted – Commercial, Residential, Utility, Subsurface, Recreational (e.g., camping), Construction Activity	10 ft*
Public Access – Agricultural, Surface Recreational, Vehicle Parking, Surface Supply Storage	4 ft (1.22 m)
Limited Public Access – Livestock Grazing, Wildlife Preserve	1 ft (0.30 m)
Not Yet Determined	Surface

*Assessment planning at construction sites for any projected end use requires looking at the possibility of UXO presence 4 feet below planned excavation depths.

Source: *DoD Ammunition and Explosives Safety Standards*, DoD Directive 6055.9-STD, Chapter 12, June 2004, rev. 5.
The DDESB is in the process of revising Chapter 12 of DoD 6055.9-STD**.**

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

U.S. Department of Defense, Operation and Environmental Executive Steering Committee for Munitions (OEESCM). ***Draft Munitions Action Plan: Maintaining Readiness through Environmental Stewardship and Enhancement of Explosives Safety in the Life Cycle Management of Munitions***. Draft Revision 4.3, Feb. 25, 2000.

U.S. Department of Defense and U.S. Environmental Protection Agency. ***Management Principles for Implementing Response Actions at Closed, Transferring, and Transferred (MRSs) Ranges***. Mar. 7, 2000.

Information Sources

Department of Defense Explosives Safety Board (DDESB)
2461 Eisenhower Avenue
Alexandria, VA 22331-0600
Fax: (703) 325-6227
http://www.ddesb.pentagon.mil

Joint UXO Coordination Office (JUXOCO)
10221 Burbeck Road, Suite 430
Fort Belvoir, VA 22060-5806
Tel: (703) 704-1090
Fax: (703) 704-2074
http://www.denix.osd.mil/UXOCOE

Naval Safety Center, Code 40
375 A Street
Norfolk, VA 23511-4399
Tel: (757) 444-3520
http://www.safetycenter.navy.mil/

Naval Explosive Ordnance Disposal Technology Division
(NAVEODTECHDIV)
UXO Countermeasures Department, Code 30U
2008 Stump Neck Road
Indian Head, MD 20640-5070
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Guidance Documents

U.S. Air Force. ***Civil Engineering – Disposal of Real Property***. AFI 32-9004; July 21, 1994.

U.S. Air Force. ***Explosive Ordnance Disposal***. AFI 32-3001; Oct. 1, 1999.

U.S. Air Force, ***Explosive Ordnance Disposal***. Directive AFPD 32-30, July 10, 1994.

U.S. Air Force. ***Inspection, Storage, and Maintenance of Non-Nuclear Munitions***. AFI 21-201; Dec. 1, 2000.

U.S. Air Force. ***Non-nuclear Munitions Safety Board***. AFI 91-205; July 1, 1998.

U.S. Air Force. ***Safety: Explosives Safety Standards***. Air Force Manual 91-201; Mar. 7, 2000.

U.S. Army, Headquarters, ***Explosives Safety Policy for Real Property Containing Conventional Ordnance and Explosives***. DACS-SF HQDA LTR 385-00-2, June 30, 2000.

U.S. Army Corps of Engineers. ***Engineering and Design – Ordnance and Explosives Response***. Manual No. 1110-1-4009, June 23, 2000.

U.S. Army Corps of Engineers. ***Engineering and Design – Safety and Health Aspects of HTRW Remediation Technologies***. Engineer Manual (EM) 1110-1-4007; Sept. 30, 1999.

U.S. Army Corps of Engineers, ***Engineering and Design – Ordnance and Explosives Response***. Pamphlet No. 1110-1-18; Apr. 24, 2000.

U.S. Army Corps of Engineers. ***Safety and Occupational Health Requirements for Hazardous, Toxic, and Radioactive Waste (HTRW) Activities***. ER 385-1-92; Sept. 1, 2000.

U.S. Army Corps of Engineers, Huntsville Center. ***Basic Safety Concepts and Considerations for Ordnance and Explosives Operations***. EP 385-1-95a; June 29, 2001.

U.S. Army Corps of Engineers, Huntsville Center, Ordnance and Explosives Center of Expertise. ***Public Involvement Plan for Ordnance and Explosives Response***. Interim Guidance (Draft ETL 1110-1-170); Sept. 15, 1995.

U.S. Departments of the Army, Navy, and Air Force. ***Interservice Responsibilities for Explosive Ordnance Disposal***. Joint Army Regulation 75-14, OPNAVINST 8027.1G, MCO 8027.1D, AFI 32-3002; Feb. 14, 1992.

U.S. DoD. ***Defense Transportation Regulation Part II, Cargo Movement***. DoD 4500.9-R; May 2003. Website: http://www.transcom.mil/j5/pt/dtr.html.

U.S. DoD (Department of Defense). ***DoD Ammunition and Explosives Safety Standards***. DoD 6055.9-STD; July 1999.

U.S. DoD. ***DoD Ammunition and Explosives Safety Standards***. DoD 6055.9-STD, Rewrite 4.5; January 2004.

U.S. DoD. ***DoD Ammunition and Explosives Safety Standards***. DoD 6055.9-STD, October 2004.

U.S. DoD. ***DoD Contractors' Safety Requirements for Ammunition and Explosives***. Instruction 4125.26; Apr. 4, 1996 (updated Dec. 6, 1996).

U.S. DoD. ***DoD Explosives Safety Board (DDESB) and DoD Component Explosives Safety Responsibilities***. Directive 6055.9; July 29, 1996.

U.S. DoD. ***Environmental and Explosives Safety Management on Department of Defense Active and Inactive Ranges Within the United States***. Directive 4715.11; Aug. 17, 1999.

U.S. DoD Explosives Safety Board. ***Changes to Department of Defense Ammunition and Explosives Hazard Classification Procedures***. DDESB-KT, July 25, 2001.

U.S. DoD Explosives Safety Board, DDESB-KO. ***Guidance for Clearance Plans***. Feb. 27, 1998.

U.S. EPA, ***Institutional Controls and Transfer of Real Property Under CERCLA Section 120(h)(3)(A), (B) or (C)***. Feb. 2000.

U.S. Marine Corps. ***Ammunition and Explosives Safety Policies, Programs, Requirements, and Procedures for Class V Material***. Directive 8020.1; Oct. 18, 1995.

U.S. Marine Corps. ***Explosive Ordnance Disposal (EOD) Program***. Directive 3571.2F; Aug. 18, 1990.

U.S. Navy. ***Department of the Navy Explosives Safety Policy***. Instruction 8020.14; Oct. 1, 1999.

U.S. Navy. ***Procedures for Conducting Ammunition and Hazardous Materials (Amhaz) Handling Review Boards***. Instruction 8023.13F; Mar. 6, 1985.

U.S. Navy. ***Naval Responsibilities for Explosive Ordnance Disposal***. Instruction 8027.6E; June 1994.

U.S. Navy. ***Navy Munitions Disposition Policy***. Instruction 8026.2A; June 15, 2000.

U.S. Navy. ***Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Requirements to Conventional Explosive Ordnance Operations***. Navy Memorandum 93-20, Nov. 10, 1993.

U.S. Navy, ***U.S. Navy Explosives Safety Policies, Requirements, and Procedures, Explosives Safety Policy Manual***. OPNAV Instruction 8023.2C.; Jan. 29, 1986.

U.S. Navy, ***Ammunition and Explosives Ashore: Safety Regulations for Handling, Storing, Production, Renovation and Shipping***. NAVSEA, OP 5, Vol. 1, Rev. 6, Chg. 4; Mar., 1999.

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7.0 PLANNING MUNITIONS RESPONSE INVESTIGATIONS

Characterizing MEC contamination is a challenging process that requires specialized investigative techniques. Unlike traditional hazardous waste contamination, MEC may not be distributed in a predictable manner; MEC contamination is not contiguous, and every ordnance item and fragment is discrete. The use of existing technologies by investigators to detect anomalies, and find the ordnance, and then discriminate between UXO, fragments of exploded ordnance, and background levels of ferrous materials in soils may be technically challenging or infeasible. Locating buried munitions whose burial may not have been well documented can also be difficult. The technical and cost issues become even more daunting when the large land areas associated with many ranges (potentially tens of thousands of acres), as well as other range characteristics, such as heavy vegetation or rock strata and soils, are considered. Some level of uncertainty is expected for any subsurface environmental investigation; however, the consequences of potential uncertainties related to munitions response investigations (e.g., accidental explosion resulting in possible death or dismemberment) elevate the level of public and regulatory concern.

The purpose of this chapter is to outline an approach to planning a munitions response investigation using a systematic planning process and to identify the choices you will make to tailor the investigation to your site. Specifically, this chapter is designed to:

- Present an overview of the elements and issues associated with sampling and the systematic planning process (SPP).
- Discuss development of the goals of the investigation.
- Help you prepare for the investigation: gathering information, preparing the conceptual site model, and establishing data quality objectives.

Chapter 8 continues the discussion of the planning process, focusing on considerations in the development of investigation and response strategies that will meet the goals and objectives for the site.

> **What Is the Systematic Planning Process?**
>
> "Systematic planning" is a generic term used to describe a logic-based scientific process for planning environmental investigations and other activities. EPA developed a systematic planning process called the Data Quality Objectives Process and published a document called *Guidance for the Data Quality Objectives (DQO) Process* (EPA/600/R-96/055, 1996). While not mandatory, this seven-step process is recommended for many EPA data collection activities. The planning processes used by other Federal agencies do not necessarily follow the seven steps of the DQO process. For example, using different terminology, but a similar systematic planning process, the U.S. Army Corps of Engineers adopted a four-step Technical Project Planning Process to implement systematic planning for cleanup activities. Confusion is caused by the different names applied to similar processes used by different Federal agencies and departments. Therefore, EPA is moving toward a more general descriptor of this important process that can be used to describe a number of different systematic planning processes. (EPA Order, "Policy and Program Requirements for the Mandatory Quality System" (5360.1 A2, May 2000).

Neither Chapter 7 nor Chapter 8 focuses on the investigation of munitions constituents except where there are issues unique to such constituents that should be addressed. Except for unique issues associated with munitions constituents such an investigation would be similar to the investigation of other hazardous wastes, and the numerous guidance documents that have been written on the investigation of hazardous wastes would apply. (See "Sources and Resources" at the end of this chapter for guidance on conducting hazardous waste investigations.) Instead, this chapter addresses site investigations of MEC, which generally consists of one of three types of waste products:

- Munitions that have not exploded, including UXO (e.g., duds) or buried or otherwise discarded munitions, including bulk explosives
- Ordnance fragments from exploded munitions that may retain residues of sufficient quantity and type to be explosive
- Concentrations of reactive and/or ignitable materials in soil (e.g., munitions constituents in soil from partly exploded, i.e., low-order detonation, or corroded munitions items that are present in sufficient quantity and weight to pose explosive hazards)

7.1 Overview of Elements of Site Characterization

An effective strategy for site characterization uses a variety of tools and techniques to locate and excavate MEC and to ensure understanding of uncertainties that may remain. The selection and effective deployment of these tools and techniques for the particular investigation will be determined through the systematic planning process. The following steps are included in a typical investigation:

- Use of historical information to:
  - Identify what types of ordnance were used at the facility and where they were used
  - Identify areas of the facility where there is no evidence of ordnance use, thereby reducing the size of the area to be investigated
  - Prioritize the investigation in terms of likelihood of ordnance presence, type of ordnance used, potential hazard of ordnance, public access to the area, and planned end uses
  - Consider the need to address explosives safety issues prior to initiating the investigation
- Visual inspection of range areas to be investigated, and surface response actions to facilitate investigation
- Selection of appropriate geophysical system(s) and determination of site-specific performance of the selected geophysical detection system
- Establishment and verification of measurement quality objectives in the sampling and analysis methodologies (QA/QC measurements)
- Geophysical survey of areas of concern (i.e., areas likely to be contaminated)
- Analysis of geophysical survey data to identify metallic anomalies, and possibly to help discriminate between MEC, ordnance fragments, and non-MEC-related metal waste, and QA/QC of that analysis
- Anomaly reacquisition and excavation to identify the sources of the geophysical anomalies, to verify geophysical mapping results, and to gather data on the nature and extent of MEC contamination
- Analysis of investigation results to test assumptions and set priorities for future work

Some of the particular challenges and issues to consider in using these tools include the following:

- Finding adequate and reliable historical information on the former uses of ranges and the types of munitions likely to be found
- Matching the particular detection technology to the type of UXO expected and to the geology, vegetation, and the topography of the range
- Confirming the field detection data
- Establishing a clear understanding of the nature and extent of UXO contamination and resulting uncertainty
- Performing the investigation in stages that refine its focus in order to ensure that the data collected are appropriate to the decision required
- Optimizing available resources

There is no single solution for resolving the challenges of a MRS characterization, but the starting place for every investigation is to establish the decisions to be made and the resulting goal(s) of the investigation.

7.2 Overview of Systematic Planning

As with any environmental investigation, designing the range investigation and judiciously applying investigative tools must take place in the context of a systematic planning process (Figure 7-1). The process starts with identifying the decision goals of the project. Available information is then used to identify data requirements that support the decision goals and to define the objectives of the investigation. Finally, the sampling strategy of the investigation is tailored to ensure that the data gathered are of appropriate quantity and quality to support the decision goals. Each stage of the systematic planning process is carefully refined by the succeeding stages. Figure 7-1 outlines how the systematic planning process is used to design the investigation to meet the requirements of the project.

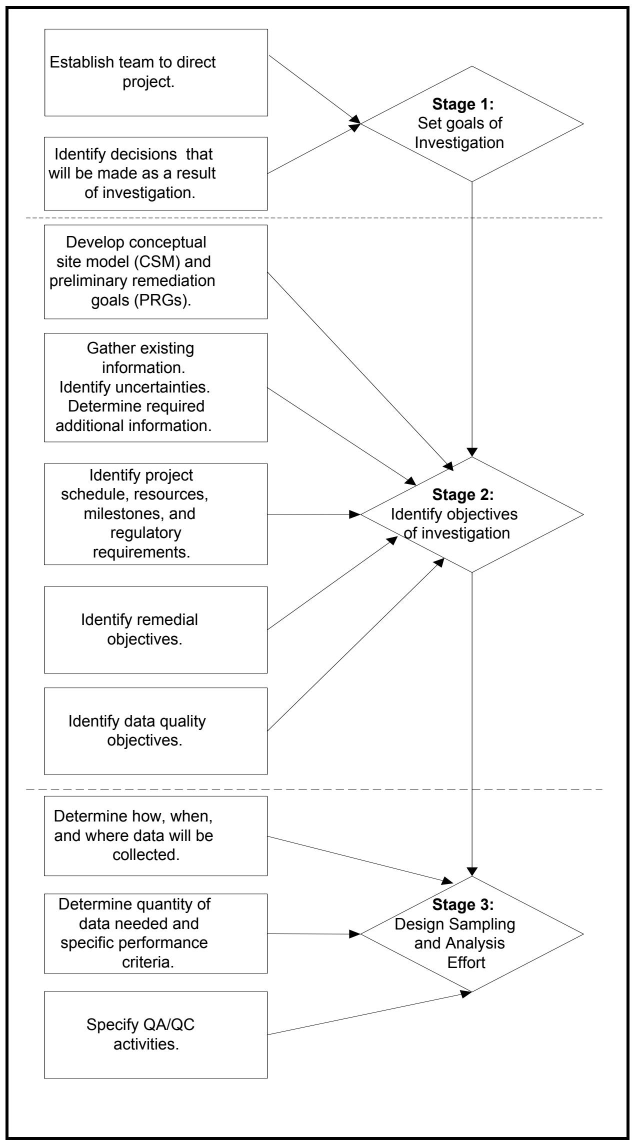

Figure 7-1. Systematic Planning Process

Although the figure outlines an apparently sequential process, in practice, the process involves a number of concurrent steps and iterative decisions.

The steps you will take to plan and carry out your investigation will be similar regardless of which regulatory program governs the investigation (e.g., removal or remedial action under CERCLA or investigations performed under RCRA). The significance and complexity of any particular step will depend on your decision goals, the data quality objectives (DQOs), and a variety of site-specific conditions.

The purpose of any investigation is to obtain enough information to make the decisions that were identified as decision goals of the investigation. It is important, however, that you understand the uncertainty associated with the available data on the presence, absence, or types of MEC so that decisions you make are not based on erroneous assumptions. For example, using limited sampling data to estimate the density of UXO may be sufficient to estimate the cost of a response to a 2-foot depth. On the other hand, a higher level of certainty will be required when the decision goal is a no-action decision and the planned land use is unrestricted.

As with any environmental investigation, you will want to collect data in appropriate stages and be prepared to make changes in the field. Some kinds of information may not be needed if the initial information you collect answers basic questions. In addition, as you collect data, you may find that your initial hypotheses about the site were not correct. New information may cause your investigation to go in different directions. Anticipating field conditions that may potentially modify your investigation, and planning and articulating the decision rules that can lead to such changes, will foster cooperation among your project team, the DoD investigators, the regulators, and the public.

7.3 Stage 1: Establishing the Goal(s) of the Investigation

The goal of the investigation is to obtain the information required to make site-specific decisions. Therefore, the stated goal will reflect the final decision goal (e.g., action or no-action decision). As used in the discussion that follows, the goals of the investigation differ from the objectives of the investigation. The objectives are the specific data needs for achieving the goals.

Establishing the goals of the investigation requires two key steps. The first step involves selecting an appropriate project team to guide the investigation. The second step is to identify the decisions that will be made at the conclusion of the site characterization process. Both elements will guide the remaining steps of the investigation process.

7.3.1 Establishing the Team

To be scientifically based, the investigation must be planned and managed by those people who will use the data to make decisions. This approach ensures that all of the data needed for decision making are acquired at an appropriate level of quality for the decision. The project team generally includes an experienced project manager, MEC personnel, data processing experts, chemists, geophysicists, a logistics coordinator, health and safety personnel, natural/cultural resource experts, and regulatory personnel from the appropriate Federal, State, Tribal, and local regulatory agencies. Involving all of the potential end users in the planning process also has other important outcomes:

- **Common understanding among all of the parties of how the data will be used** — Subsequent review of work plans, with a clear understanding of the decision goals in mind, will result in comments targeted to the agreed-upon goals of the investigation, not unspoken assumptions about those goals.

- **Minimization of rework** — If all of the decision makers and data users are involved from the beginning of the study, the study design will be more likely to include objectives that clearly relate to the goals, and the various investigative tools will be targeted appropriately.

A team-based approach can expedite the process of making decisions and, ultimately, of reaching project goals. By definition, this consensus-oriented approach allows all team members to have input into the project goals, as well as to identify the information needed and methods to be employed to achieve the goals. Further, with this approach, the outcome of the project is more likely to be accepted by all parties later, resulting in a more efficient and less contentious decision-making process.

It may also be important to include non-DoD landowners of munitions response areas (MRAs), and other stakeholders with contributions to make to the planning process. This inclusion can either be as a member of the team or through various public involvement mechanisms.

7.3.2 Establishing the Goals of the Site Characterization Process

Establishing the decision goals of the project will ultimately determine the amount of uncertainty to be tolerated, the area to be investigated, and the level of investigation required. The following are examples of decision goals:

- Confirm that a land area has or has not been used for munitions related activity in the past.
- Prioritize one or more MRS for response.
- Conduct a limited surface clearance effort to provide for immediate protection of nearby human activity.
- Identify if response action will be required on the MRS under investigation (to decide if there is a potential hazard, and to make an action/no-action decision).
- Identify the appropriate clearance depths and select appropriate removal technologies for the MRS under investigation.
- Transfer clean property for community use.

A particular investigation may address one or several decision goals, depending on the scope of the project.

Conducting Investigations in Phases

Most range investigations take place in phases. The first phase of the process involves determining what areas are to be investigated. The range is divided into **MRAs** using a variety of factors, including, but not limited to, evidence of past ordnance use and safety factors, cost/prioritization issues, and characteristics of the areas to be investigated.

The individual munitions response activities also often proceed in stages. Prior to detailed subsurface investigation, a surface removal action is usually conducted to ensure that the property is "safe" for the subsurface investigations. The subsurface investigations themselves often take place in stages. The first is a nonintrusive stage that uses geophysical detection equipment designed to detect subsurface anomalies. Generally, positional data are collected as the geophysical survey is being conducted. The second stage involves processing of data to co-locate geophysical data with geographic positional data and analyzing the resulting data set to identify and locate geophysical anomalies that may be MEC. The third stage, called anomaly reacquisition, is designed to verify the location of anomalies. Finally, anomaly excavation is conducted, and the results are fed back into the anomaly identification process. Anomaly excavation includes a verification of clearance using geophysical detectors.

7.4 Stage 2: Preparing for the Investigation: Gathering Information To Design a Conceptual Site Model and Establishing Sampling and Analysis Objectives

Once the decision goals of the investigation are identified, five steps provide the foundation for designing the sampling and analysis plan that will provide the information required to achieve the desired decision. These five steps result in the project objectives:

- Developing a working hypothesis of the sources, pathways, and receptors at the site (conceptual site model, or CSM) and their locations on the site
- Developing preliminary remediation goals (PRGs)
- Comparing known information to the CSM, and identifying information needs
- Identifying project constraints (schedules, resources, milestones, and regulatory requirements)
- Identifying remedial objectives

These steps are iterative, so both the PRGs and the CSM will likely change as more information is gathered. Documentation of the CSM is explained at the conclusion of this section.

7.4.1 The Conceptual Site Model (CSM)

The CSM establishes a working hypothesis of the nature and extent of MEC contamination and the likely pathways of exposure to current and future human and ecological receptors. A good CSM is used to guide the investigation at the site. The initial CSM is created once project decision goals are defined and historical information on range use and the results of previous environmental investigations are gathered. It then continues to evolve as new data about the site are collected. In other words, as information is gathered at each stage of the site characterization process, the new data are used to review initial hypotheses and revise the CSM. The CSM describes the site and its environmental setting, and presents hypotheses about the types of contaminants, their routes of migration, and potential receptors and exposures routes. Key pieces of initial data to be recorded in the CSM include, but are not limited to:

- The topography and vegetative cover of various land areas
- Past munitions-related activities (e.g., munitions handling, weapons training, munitions disposal) and the potential releases that may be associated with these activities (e.g., buried munitions, dud-fired UXO, kick-outs from OB/OD areas)

- Expected locations and the depth and extent of contamination (based on the MEC activities)
- Likely key contaminants of concern
- Potential exposure pathways to human and ecological receptors (including threatened and endangered species)
- Environmental factors such as frost line, erosion activity, and the groundwater and surface water flows that influence or have the potential to change pathways to receptors
- Human factors that influence pathways to receptors, such as unauthorized transport of MEC
- Location of cultural or archeological resources
- The current, future, and surrounding land uses

7.4.2 Assessment of Currently Available Information To Determine Data Needs

The site-specific objectives of the investigation are ultimately based on acquiring missing information that is needed to make the required decision. In order to establish the objectives of the investigation, it is necessary to first identify what is known (and unknown) about the MRS. Your investigation will focus on what is not known, and key questions will improve your understanding of the elements of the risk management decision that is to be made (such as explosive potential of the ordnance, pathways of exposure, and likelihood of exposure), and the costs, effectiveness, and risks associated with remediation. The following are typical questions with which you will be concerned:

- What types of ordnance were used on the range?
- What are the likely range boundaries?
- Is there evidence of any underground burial pits possibly containing MEC on the site?
- At what depth is the MEC likely to be located?
- What are the environmental factors that affect both the location and potential corrosion of MEC?
- Is there explosive residue in the soil?
- Is there explosive residue in ordnance fragments?

7.4.2.1 *Historical Information on Range Use and Munition Types*

Historical data are an important element in effectively planning site characterization. Because many ranges and other ordnance-related sites have not been used in years, and because many ranges encompass thousands of acres of potentially contaminated land, historical information is critically important in focusing the investigation.

Sources of Historical Data

- National Archives
- U.S. Center of Military History
- History offices of DoD components such as the Naval Facilities Command Historian's Office and the Air Force Historical Research Agency
- Repositories of individual service mishap reports
- Smithsonian Historical Information and Research Center
- Real estate documents
- Historical photos, maps, and drawings
- Interviews with base personnel

Historical information can be obtained from many sources, including old maps, aerial photographs, satellite imagery, interviews with former or current personnel, records of military operations, archives of range histories and types of munitions used, and records from old ammunition supply points, storage facilities, and disposal areas. Historical information is important to determining the presence of MEC, the likely type of ordnance present at the MRA/MRS, the density of the ordnance, and the likely location (both horizontal and vertical) of the ordnance. (See "Sources and Resources" at the end of this chapter.)

Historical information is important for assessing the types of munitions likely to be found on the range, their age, and the nature of the explosive risk. Potential sources of this information include ammunition storage records, firing orders, and EOD and local law enforcement reports. This information can be used to select the appropriate detection tools and data processing programs to be used during the characterization, as well as to establish safety procedures and boundaries based on anticipated explosive sensitivity and blast potential. Historical information based on past UXO and scrap finds may provide data about the type, size, and shape of the munitions items on the range, which could simplify MEC identification and clarify safety requirements during the detection phase. Such historical data could help investigators plan for the potential explosive hazards (e.g., thermal, blast overpressure, or fragmentation grenades, or shock hazards), which will dictate separation distance requirements for excavation sites, open detonation areas, and surrounding buildings; public traffic routes; and other areas to be protected.

Munition Burial Pits

Underground munitions burial pits present unique challenges to a site characterization. Frequently, the existence of burial pits is not known; if they are known to exist, their exact locations may not be known. Many munitions burial pits are so old that records do not exist and individuals who were aware of their existence at one time are no longer alive. An example of an old munitions burial pit is the Washington, DC, Army Munitions Site at Spring Valley. This site was last used for military purposes during World War I and was developed as residential housing beginning in the 1920s. In 1993, MEC was found, and removal and remedial actions were performed. However, in 1999, an additional cache of ordnance was found adjacent to a university on the former installation, necessitating emergency removal actions.

Historical information is also necessary for estimating the probable locations of MEC in the MRA under investigation. This information will affect the phasing of the investigation, the technical approach to detection and discrimination of anomalies, the extent of sampling required, the cost of remediation, and the safety plan and procedures used. There may be some areas where, given the site conditions, extent, or type of UXO present, physical entry onto the site or intrusive investigations will be too dangerous. In some cases the suspected amount of UXO at the MRS will lead to a decision to not clear the area because of the high number of short-term risks.

Historical information is needed in order to estimate the location of potential MEC contamination, both to focus the investigation (and identify likely MRS) and to reduce the footprint of potential MEC contamination by eliminating clean areas from the investigation. Identifying areas of potential MEC contamination may be more difficult than is at first apparent. For decades, many facilities have served a number of different training purposes. Although an impact area for a bombing range may be obvious, the boundaries of that area (including where bombs may have accidentally dropped) are often not clear. In addition, land uses on military bases change, just as they do in civilian communities around the country. Training activities using munitions may have taken place in any number of locations. In some cases, land uses will change and a building or a recreational area, such as a golf course, will be built over an MRS. In many cases ranges were closed shortly after World War II, thus giving ample time for forests and other vegetative regrowth to obscure pastures. Finally, munitions may have been buried at various locations on the base, sometimes in small quantities, without the knowledge or approval of the base commanders.

While historical information is more likely to be used to determine the presence (as opposed to the absence) of MEC, comprehensive and reliable historical information may make it possible to reduce the area to be investigated or to eliminate areas from munitions response investigation. Early elimination of clean areas on bases where a lot of range-related training activity took place may require a higher degree of certainty than on bases where there was no known ordnance-related training activity. For example, an isolated forested wetland might be eliminated from further investigation under certain circumstances. This might be possible if an archives search report indicates the area was never used for training or testing, it was never accessible by vehicle, and these assumptions can be documented through a series of aerial photographs, beginning at the time the base was acquired by the military through the time of base closure. Alternatively, potential MRAs on bases with a history of a variety of ordnance-related training activities, and large amounts of undocumented open space (or forested lands), may be more difficult to eliminate.

Historical data are often incorporated into an archives search report, a historical records search report, or an inventory project report, management tools that are often compiled by MEC experts. These reports incorporate all types of documents, such as memoranda, letters, manuals, aerial photos, real estate documents, and so forth, from many sources. After an analysis of the collected information and an on-site visit by technical personnel, a map is produced that shows all known or suspected MRSs on the site at the location.

7.4.2.2 *Geophysical and Environmental Information*

Depending on the level of detail required for the investigation, additional information might be gathered, such as:

- Results of previous investigations that may have identified both UXO and explosives-contaminated soil.
- Geological data that affect the movement (and therefore location) of UXO, the potential corrosion of MEC containers/casings, and the ability of detection equipment to locate UXO.

Information about geological conditions that will affect the movement, location, detection, and potential deterioration of ordnance and nonordnance explosives may be available on-site from previous environmental investigations (e.g., investigations conducted on behalf of the Installation Restoration Program). The significance of this information is discussed in more detail in Chapter 3.

A limited list of specific types of information that may be important (depending on the purpose of the investigation) is provided in Table 7-1. Some of the information may be so critical to the planning of the investigation that it should be obtained during the planning phase and prior to the more detailed investigation. Other information will be more challenging to gather, such as depth and flow direction of groundwater. If the necessary information is not available from previous investigations, it will likely be an important aspect of the MRA investigation.

Table 7-1. Potential Information for Munitions Response Investigation

Information	Purpose for Which Information Will Be Used
Background levels of ferrous metals	Selection of detection technology. Potential interference with detection technologies, such as magnetometers.
Location of bedrock	Potential depth of MEC and difficulties associated with investigation.
Location of frost line	Location of MEC. Frost heave potential to move MEC from anticipated depth.
Soil type and moisture content	Penetration depth of MEC. Reliability of geophysical detection. Potential for deterioration/corrosion of casings. Potential for release of munitions constituents.
Depth and movement of groundwater	Potential for movement of MEC and for deterioration/corrosion of containment. Potential for leaching of munition residues.
Location of surface water, floodplains, and wetlands	Potential location of explosive material. Potential pathway to human receptors; potential for movement of MEC and for deterioration/corrosion of munition casings; potential leaching of munition residues; selection of detection methods.
Depth of sediments	MEC located in wetlands or under water. Location, leaching, and corrosion of MEC; selection of detection methods.
Topography and vegetative cover	Potential difficulties in investigation, areas where clearance may be required. Selection of potential detection technologies.
Location of current land population	Potential for exposure.
Current use of range and surrounding land areas	Potential for exposure.
Information on future land use plans	Potential for exposure.

7.4.3 <u>Key Components of Munitions-Related CSMs</u>

7.4.3.1 *Developing the CSM*

The ability to develop a good working hypothesis of the sources and potential releases associated with MEC will depend on your understanding the munitions-related activities that took place on the land area to be investigated, the primary sources of MEC contamination, the associated release mechanisms, and the expected MEC contamination. Tables 7-2 and 7-3 summarize these characteristics for typically expected ordnance-related activities. Table 7-4 describes the elements of the firing range that should be located on your CSM.

Table 7-2. Munitions-Related Activities and Associated Primary Sources and Release Mechanisms

Munitions-Related Activity	Primary Source	Release Mechanisms
Munitions storage and transfer	Ammunition pier	Mishandling/loss (usually into water)
	Storage magazine	Mishandling/loss, abandonment, burial
	Ammunition transfer point	Mishandling/loss, abandonment, burial
Weapons training	Firing points	Mishandling/loss, abandonment, burial
	Target/impact areas	Firing
	Aerial bombing targets	Dropping
	Range safety fans	Firing, dropping
Troop training	Training/maneuver areas	Firing, intentional placement (minefields), mishandling/loss, abandonment, burial
	Bivouac areas	Mishandling/loss, abandonment, burial
Munitions disposal	Open burn/open detonation areas	Kick-outs, low-order detonations
	Large-scale burials	Burial

Table 7-3. Release Mechanisms and Expected MEC Contamination

Release Mechanism	Expected MEC Contamination
Mishandling or loss	Fuzed or unfuzed ordnance, possibly retrograde, bulk MEC, MC
Abandonment	
Burial	
Firing or dropping – complete detonation	MEC debris (fragmentation), munitions
Firing or dropping – incomplete detonation	MEC debris (fragmentation), pieces of MEC, MC
Firing or dropping – dud fired	UXO
Intentional placement	Mines (usually training), booby traps
Kick-outs	MEC debris, munitions components, UXO
Low-order detonations	MEC debris (fragmentation), pieces of MEC, MC

Table 7-4. Example of CSM Elements for Firing Range

Range Configuration	Description	MEC Concerns
Range fan	The entire range, including firing points, target areas, and buffer areas	All of those listed below, depending upon area
Target or impact area	The point(s) on the range to which the munitions fired were directed	Dud-fired UXO, low-order detonations with munition fragments and containing munitions constituents that may be reactive or ignitable; munitions constituents
Firing points	The area from which the munitions were fired	Munitions constituents from propellants; buried or abandoned munitions.
Buffer zone	Area outside of the target or impact area that was designed to be free of human activity and act as a safety zone for munitions that do not hit targets	Same as target or impact area, but likely much lower density of UXO and, therefore, munitions constituents

The same process is used to develop the CSM for explosives and ordnance manufacturing areas. Tables 7-5 and Table 7-6 illustrate the types of munitions-related activities, sources and releases associated with explosives and ordnance manufacturing.

Table 7-5. Munitions-Related Activities and Associated Primary Sources and Release Mechanisms for Explosives and Munitions Manufacturing

Munitions-Related Activity	Primary Source	Release Mechanisms
Explosives manufacturing (e.g., TNT)	Manufacturing areas	Spillage, mishandling, routing of effluent
	Storage areas	Mishandling, abandonment, or loss
	Transfer areas	Mishandling, abandonment, or loss
	Burning and associated disposal areas	Incomplete burning and associated leaching
	Burial areas	Burial
Munitions manufacturing (load, assemble, and pack)	Loading areas	Spillage or mishandling
	Storage areas	Spillage, and mishandling, abandonment, or loss
	Test ranges	See Table 7-2
	Disposal areas	See Table 7-2

Table 7-6. Release Mechanisms and Expected MEC Contamination for Munitions Manufacturing

Primary Source	Release Mechanism	Expected MEC Contamination
Explosives manufacturing areas	Spillage, mishandling, or routing of effluent	Toluene, sulfuric acid, nitric acid, waste acids, nitroaromatic compounds
Explosives storage areas	Mishandling, abandonment, or loss	TNT, sulfuric acid, nitric acid, toluene, waste acids, yellow/red water, nitroaromatic compounds
Explosives transfer areas	Mishandling, abandonment, or loss	TNT, yellow/red water, nitroaromatic compounds
Explosives burning and associated disposal areas	Incomplete burning and associated leaching	Waste acids, TNT, nitroaromatic compounds
Explosives burial areas	Burial	Waste acids, nitroaromatic compounds
Munitions loading areas	Spillage, mishandling, abandonment, or loss	Explosives, propellants, pyrotechnics
Munitions storage areas	Spillage, mishandling, abandonment, or loss	Explosives, propellants, pyrotechnics
Munitions washout plants	Storing of treating water from demilitarization processes	TNT, pink water, any constituent or explosive train

The process of constructing the CSM involves mapping data obtained from historical records, conducting an operational analysis of the munition activity, and analyzing the ordnance-related activities that occurred on the site. Historical information on the type of activity that took place and the munitions used will be particularly important to help you identify patterns in the distribution of ordnance and the depth at which it may be found. As shown in Table 7-1, if the site was used as a projectile range, you would expect to find fired ordnance (including dud-fired rounds) primarily in the target area, buried munitions at the firing point, dud-fired rounds along the projectile path, and a few projectiles in the buffer zone. Ranges used for different purposes have different firing patterns and different distributions of MEC. At a troop training range, you might find buried munitions scattered throughout the training area if troops decided to bury their remaining munitions rather than carry them out with them.

The boundaries of suspected contamination, the geology and topography, and the areas of potential concern should be delineated during this process. Using the historical data as inputs, three-dimensional operational analyses of the anticipated locations of MEC are developed that address the expected dispersion of munitions and range fan areas as well as the maximum penetration or burial depths of the munitions used at the site. Using these data sources, you can develop an assessment of the ordnance-related activities that were conducted to develop a full picture of what is likely to be found at the site.

The purpose of developing this early CSM is to ensure that the collection of initial information will be useful for your investigation. If the conceptual understanding of the site is poor, you may need to conduct limited preliminary investigations before you develop the sampling and analysis plan. Such investigations could include a physical walk-through of the area, collection of limited geophysical data, or collection of additional historical information. In any case, you should anticipate revising the CSM at least once in this early planning phase as more data are gathered.

Specific data regarding MEC that should be addressed in a CSM include, but are not limited to:

- Munitions types
- Munitions category (e.g., unfired, inert, dud-fired)
- Filler type
- Fuze type
- Net explosive weight of filler
- Condition (e.g., intact, corroded)
- Location (coordinates)
- Depth (below ground surface)
- Compass bearing
- Propellant type

7.4.3.2 *Groundtruthing the CSM*

No matter how extensive your historical research on past ordnance-related activities is, no CSM should be completed without groundtruthing your hypothesis. Groundtruthing should consist of on-site reconnaissance of the area to be investigated in order to provide the following:

- Forensic evidence of ordnance use, including depressions in the ground caused by the impact of an ordnance item and subsequent detonation, as well as fragmented remnants of ordnance
- Verification of geological features such as topography, water bodies, and outcroppings
- Identification of environmental factors that may be at work to move ordnance, including erosion, tidal action, and frost heave
- Identification of surface ordnance that may require clearance prior to beginning the investigation, as well as provide additional evidence about past ordnance use
- Identification of vegetative features that may interfere with the investigation
- Evidence of past ordnance use not identified in historical records
- Evidence of on-site receptor activity

One of the most important considerations in the design of a good sampling and analysis plan for locating UXO may be an operational analysis of the type of weapon system (e.g., mortar, artillery) used on the range. For example, Army field manuals provide information and data that allow the calculation of areas of probable high, medium, and low impact in a normal distribution. Using available operational information, it is possible to assess the most likely distribution of UXO for a particular weapons activity and to plan a sampling strategy that optimizes the probability that UXO may be present.[116]

[116]The process of using operational analysis to design a CSM-based sampling plan is described more fully in the paper *Conceptual Site Model-Based Sampling Design*, presented to the UXO Countermine Forum 2001 by Norell Lantzer, Laura Wrench, and others.

As with any site visit of a suspected MRA, a site reconnaissance should be conducted in accordance with DDESB safety requirements and in the company of a qualified UXO technician or EOD expert.

7.4.3.3 *Documentation of the CSM*

The data points of a CSM are usually documented schematically and supplemented by a table and a diagram of relationships. The simplistic example of a CSM in Figure 7-2 illustrates the types of information often conveyed in a CSM. Depending on the complexity and number of MRAs to be investigated, the CSM may be required to show several impact areas as well as overlapping range fans. A CSM may also be presented from a top view (also called a plan view), as illustrated in Figure 7-3, and overlaid with a map created using a GIS.

Figures 7-2 and 7-3 illustrate the configuration of a typical firing range.

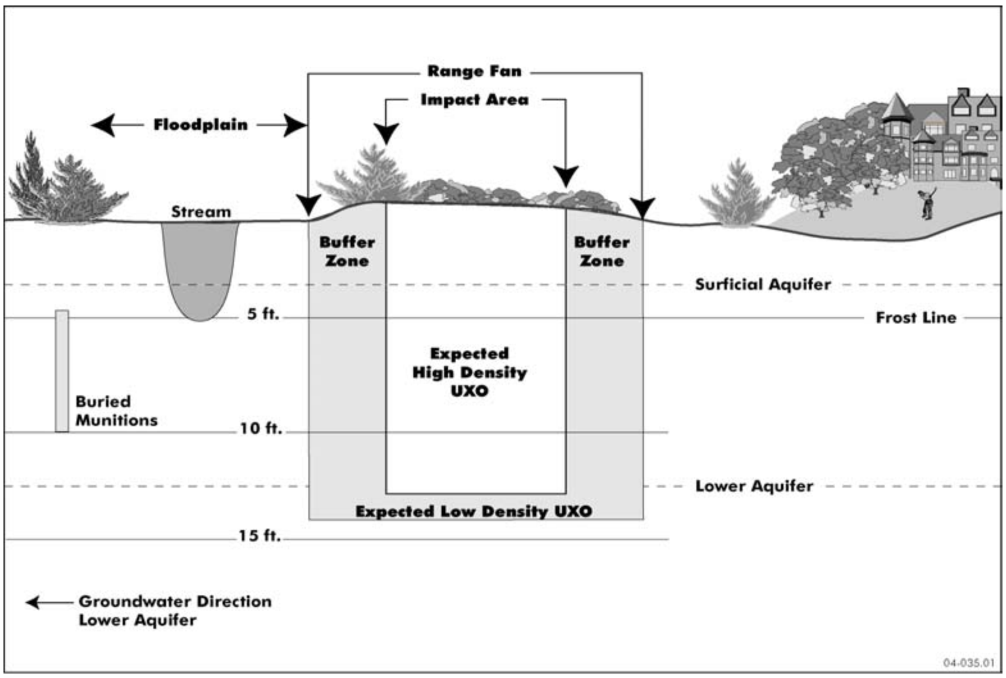

Figure 7-2. Conceptual Site Model: Vertical View

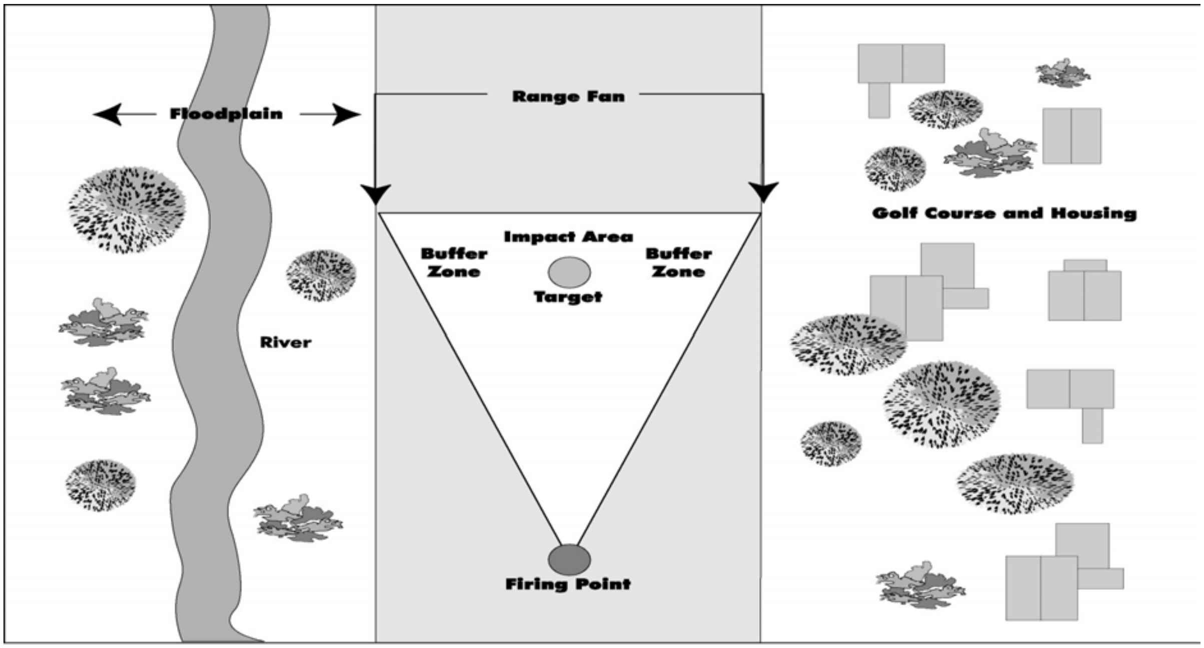

Figure 7-3. Conceptual Site Model: Plan View of a Range Investigation Area

A CSM for a closed munitions manufacturing area can be based on an operational analysis of historical operations and knowledge of site-specific information. The same concept should be applied when designing a sampling and analysis plan for the same area. The first step is to look at historical records and determine what operations were conducted there, what was manufactured, and where on the property the operations were located. Typically, explosives manufacturing areas manufactured TNT, RDX, and other explosives components. The chemicals of concern related to the manufacture of these products are TNT, toluene, nitric acid, sulfuric acid, and waste acids. For example, in a TNT manufacturing area, the CSM would focus the sampling and analysis for the COCs listed above on the operational areas in which these products are stored, transferred, handled, or disposed of, such as the following:

- Mono-, bi-, and tri-nitrating house
- Toluene and acid (sulfuric, nitric) storage areas
- Waste acid storage areas
- Finished product storage areas (e.g., bunkers or igloos for TNT)
- Burning grounds
- Yellow water and red water reservoirs
- Sewer lines and settling basins

Figure 7-4 shows what the plan view of a CSM would look like for a closed, World War II-era TNT manufacturing plant.

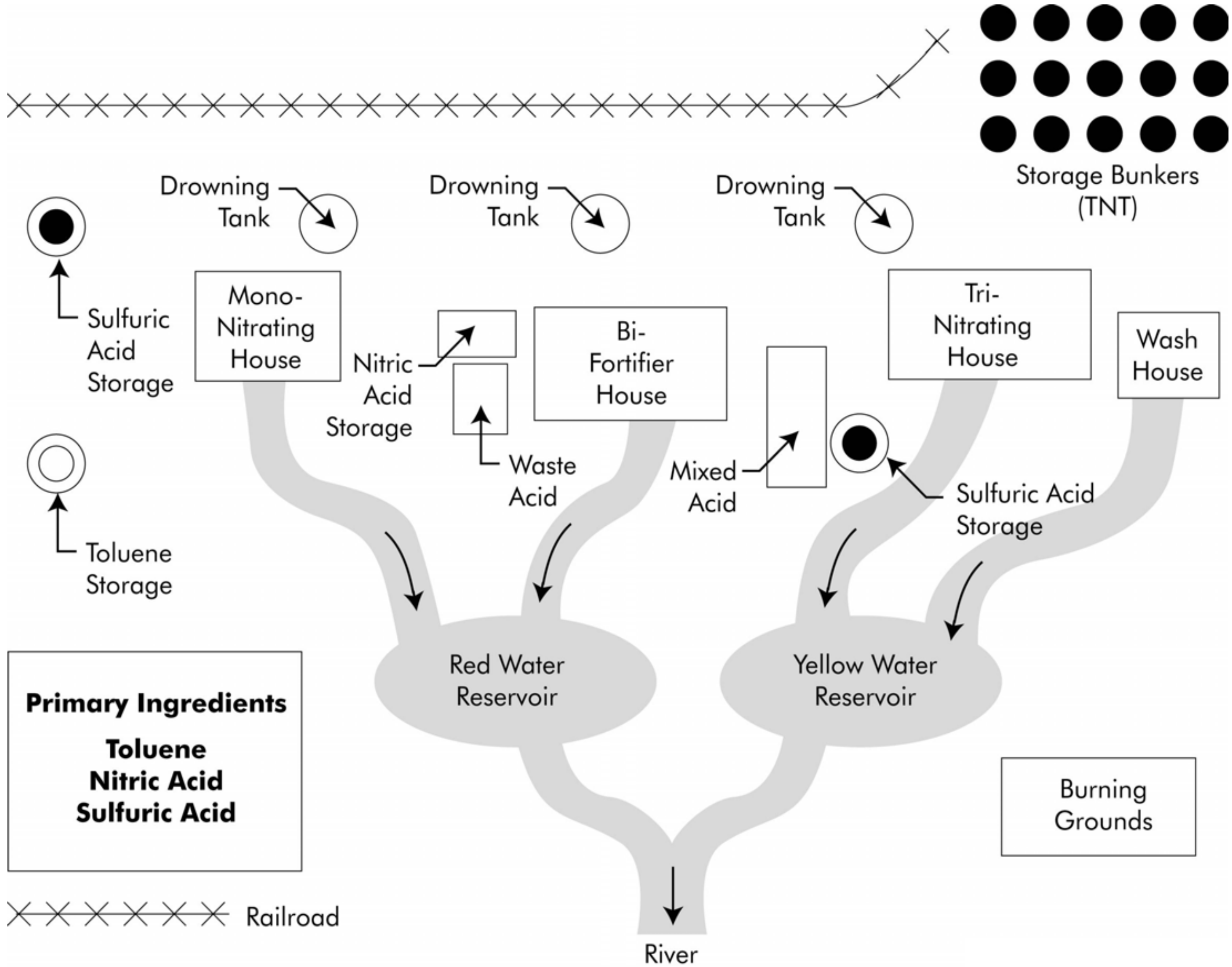

Figure 7-4. Conceptual Site Model: Plan View of a Closed TNT Manufacturing Plant

7.4.4 Preliminary Remediation Goals

> **Preliminary Remediation Goals (PRGs)**
>
> PRGs provide the project team with long-term targets to use during analysis and selection of remedial alternatives. Chemical-specific PRGs are goals for the concentration of individual chemicals in the media in which they are found. For UXO, the PRG will generally address the clearance depth for UXO.
>
> Source: U.S. EPA. Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual, Part B, Interim, December 1991.

Preliminary remediation goals (PRGs) for a munitions response are the preliminary goals pertaining to the depth of that response action and are used for planning purposes. PRGs are directly related to the specific media that are identified in your CSM as potential pathways for MEC exposure (e.g., vadose zone, river bottom, wetland area). The PRGs for response depths for munitions are a function of the goal of the investigation and the reasonably anticipated land use on the range. For example, if the goal of the investigation is to render the land surface safe for nonintrusive investigations, then the PRGs will be designed to promote surface removal of MEC from the land area. Therefore, the PRGs will require that no MEC remains on the surface of the land. On the other hand, if the goal of the investigation is to establish final response depths to protect human health from MEC hazards, then the PRGs will be based on the reasonably anticipated future land use. The PRGs in this instance may be to ensure that no MEC is present in the top 10 feet of the subsurface or above the frost line.

The PRGs may change at several points during the investigation or at the conclusion of the investigation, as more information becomes available about the likely future land use, about the actual likely depth of the MEC, about environmental conditions that may cause movement of MEC, or about the complexity and cost of the response process. The PRGs may also change during the remedy selection process as the team makes its risk management decisions and weighs factors such as protection of human health and the environment, costs, short-term risks of cleanup, long-term effectiveness, permanence, and community and State/Tribal preferences.

The first step in establishing the PRGs is to determine the current and reasonably anticipated future land use. While munitions response depth PRGs are conceptually easier to understand than chemical-specific PRGs, widely accepted algorithms and extensive guidance have been developed to establish chemical- and media-specific PRGs depending on the land use. Identifying the appropriate PRGs for MRSs can be a complex and controversial process. One approach you may consider is to use the DDESB default safety standards for range clearance as the initial PRGs until adequate site-specific data become available.

> **DoD/EPA Interim Final Management Principles on Standards for Depths of Clearance**
>
> Per DoD 6055.9-STD, removal depths are determined by an evaluation of site-specific data and risk analysis based on the reasonably anticipated future land use.
>
> - In the absence of site-specific data, a table of assessment depths is used for interim planning purposes until the required site-specific information is developed.
> - Site-specific data are necessary to determine the actual depth of clearance.

DDESB safety standards establish interim planning assessment depths that are based on different land uses, to be used for planning until site-specific data become available. In the absence of site-specific data, these standards call for a clearance depth of 10 feet for planned uses such as residential and commercial development and construction activities. For areas accessible to the public, such as those used for agriculture, surface recreation, and vehicle parking, the DDESB recommends planning for response depth of 4 feet. For areas with limited public access and areas used for livestock grazing or wildlife preserves, the DDESB recommends planning for a response depth of 1 foot.[117] In all cases, the standards call for a response depth of 4 feet below any construction. (See Chapter 6 for a more detailed description of DDESB standards.) None of these removal depths should be used automatically. For example, if site-specific information suggests that a commercial or industrial building will be constructed that requires a much deeper excavation than 10 feet, greater response depth must considered. In addition, if the response depth is above the frost line, then DDESB standards require continued surveillance of the area for frost heave movement.[118]

Site-specific information may also lead to the decision that a more shallow response action is protective. For example, if historical information and results of geophysical studies suggest that the only MEC to be found is within the top 1 foot of soil, then the actual munitions response will obviously address the depth where munitions are found (e.g., 1 foot).

> **DoD/EPA Interim Final Management Principles on Land Use**
>
> Discussions with local planning authorities, local officials, and the public, as appropriate, should be conducted as early as possible in the response process to determine the reasonably anticipated land use(s). These discussions should be used to scope efforts to characterize the site, conduct risk assessments, and select the appropriate response.

You should consider a variety of factors when identifying the reasonably anticipated future land use of the property. Current and long-term ownership of the property, current use, and pressure for changes in future use are some of the important considerations.[119] The text box below lists a number of other possible factors. In the face of uncertainty, a more conservative approach, such as assuming unrestricted land use, is prudent. In determining the reasonably anticipated future land use at a Base Realignment and Closure (BRAC) facility, you should consider not only the formal reuse plans, but also the nature of economic activity in the area and the historical ability of the local government to control future land use through deed restrictions and other institutional controls. Several sources of information about planned and potential land use at BRAC sites are available, including base reuse plans.

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[117]DoD Directive 6055.9, DoD Explosives Safety Board (DDESB) and DoD Component Explosives Safety Responsibilities, July 29, 1996.

[118]Department of Defense. *Explosive Safety Submissions for Removal of Ordnance and Explosives (MEC) from Real Property*, Memorandum from DDESB Chairman, Col. W. Richard Wright, February 1998.

[119]USEPA, OSWER Directive No. 9355.7-04, Land Use in the CERCLA Remedy Selection Process, May 25, 1995.

Factors To Consider in Developing Assumptions About Reasonably Anticipated Future Land Uses

- Current land use
- Zoning laws
- Zoning maps
- Comprehensive community master plans
- Population growth patterns and projections
- Accessibility of site to existing infrastructure (including transportation and public utilities)
- Institutional controls currently in place
- Site location in relation to existing development
- Federal/State land use designations
- Development patterns over time
- Cultural and archeological resources
- Natural resources, and geographic and geologic information
- Potential vulnerability of groundwater to contaminants that may migrate from soil
- Environmental justice issues
- Location of on-site or nearby wetlands
- Proximity to a floodplain and to critical habitats of endangered or threatened species
- Location of wellhead protection areas, recharge areas, and other such areas

7.4.5 Project Schedule, Milestones, Resources, and Regulatory Requirements

Other information used to plan the investigation includes the proposed project schedule, milestones, resources, and regulatory requirements. These elements will not only dictate much of the investigation, they will also determine its scope and help determine the adequacy of the data to meet the goals of the investigation. If resources are limited and the tolerance for uncertainty is determined to be low, it may be necessary to review the goals of the investigation and consider modifying them in the following ways:

- Reduce the geographic scope of the investigation (e.g., focus on fewer MRA/MRSs)
- Focus on surface response rather than subsurface response
- Reduce the decision scope of the investigation (e.g., focus on prioritization for future investigations, rather than property transfer)

In considering the schedule and milestones associated with the project, it is important to consider the regulatory requirements, including the key technical processes and public involvement requirements associated with the CERCLA and RCRA processes under which much of the investigation may occur, as well as any Federal facility agreements (FFAs) or compliance orders that are in place for the facility. (See Chapter 2, "Regulatory Overview.")

7.4.5.1 *Resources*

Many factors affect the scope and therefore the costs of an investigation. Although large range size is often associated with high costs, other factors can affect the scope and costs of an investigation:

- Difficult terrain (e.g., rocky, mountainous, dense vegetation)
- High density of MEC
- Depth of MEC
- Anticipated sensitivity of MEC to disturbance or other factors that may require

extraordinary safety measures

Key factors to consider when estimating the cost of the investigation include the following:

- **Site preparation** may include vegetation clearance, surface UXO removal, and the establishment of survey control points. If there is little vegetation at the site and/or if the UXO detection can be conducted without removing the vegetation, the costs can be significantly reduced. In addition, limiting the vegetation clearance can also reduce the impacts on natural and cultural resources, as discussed in the next text box.
- **Geophysical mapping** requires personnel, mapping, and navigation equipment. The operational platform for the selected detection tool can have a major impact on the costs of a site characterization.
- The **data analysis** process requires hardware and software to analyze the data gathered during the geophysical mapping to identify and classify anomalies. Data analysis can be conducted in real time during the investigation phase or off-site following the detection, with the latter generally being more expensive than the former.
- **Anomaly investigation** includes anomaly reacquisition and excavation to determine anomaly sources and to test the working hypotheses. Excavation can be very expensive; the greater the number of anomalies identified as potential UXO, the higher the cost.

Because the costs of investigation activities are based in large part on the acreage of the area to be characterized, most methods used to reduce the cost of the investigation involve reducing the size of the sampling area. Some of the techniques used to reduce costs overlap with other tools already described that improve the accuracy of an investigation. For example, a comprehensive historical search enables the project team to minimize the size of the area requiring investigation. Statistical sampling methods are frequently used to reduce the costs of site investigation. These methods and the controversy over the methods are discussed in Section 8.3.2.

Vegetation Clearance

In addition to the high monetary costs of preparing an area to be cleared of UXO, the environmental costs can also be very high. If the project team decides that vegetation clearance is necessary in order to safely and effectively clear UXO from a site, they should aim to minimize the potentially serious environmental impacts, such as increased erosion and habitat destruction, that can result from removing vegetation. The following are three land clearing methodologies:

- **Manual removal** is the easiest technique to control and allows a minimum amount of vegetation to be removed to facilitate the UXO investigation. Tree removal should be minimized, with selective pruning used to enable instrument detection near the trunks. If trees must be removed, tree trunks should be left in place to help maintain the soil profile. Manual removal results in the highest level of potential exposure to UXO of the personnel involved and should not be used where vegetation obscures the view of likely UXO locations.
- **Controlled burning** allows grass and other types of ground cover to be burned away from the surface without affecting subsurface root networks. The primary considerations when using controlled burning are ensuring that natural or manmade firebreaks exist and that potential air pollution is controlled. Favorable weather conditions will be required.
- **Defoliation** relies on herbicides to defoliate grasses, shrubs, and tree leaves. Manual removal of the remaining vegetation may be necessary. Sensitivity of groundwater and surface water bodies to leaching and surface runoff of herbicides will be important considerations.

7.4.5.2 *Regulatory Requirements*

Regulatory requirements come from a variety of laws and regulations, both State and Federal. The particular requirements that will be most applicable (or relevant and appropriate) to range cleanup activities are the Federal and State RCRA requirements for hazardous waste transportation, treatment, storage, and disposal. Other regulatory requirements may be related to the specific pathways of concern, for example, groundwater cleanup levels. Chapter 2 of this handbook provides an overview of regulatory requirements that may apply, since knowledge of the applicable requirements will be important to planning the investigation.

Since many munitions response investigations will take place under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), it is important to keep in mind that even if not directly and legally applicable to the MEC activity or investigation, Federal and State laws may be considered to be "relevant and appropriate" by regulators. If the laws are considered relevant and appropriate, they are fully and legally applicable to a CERCLA cleanup activity.[120]

Important regulatory requirements that may affect both the investigation and the cleanup of the MRA include, but are not limited to, the following:

- CERCLA requirements for removal and remedial actions (including public and State/Tribal involvement in the process)
- RCRA requirements that determine whether the waste material is to be considered a solid waste and/or a hazardous waste
- Requirements concerning the transportation and disposal of solid and hazardous wastes
- Regulatory requirements concerning open burning/open detonation of waste
- Regulatory requirements concerning incineration/thermal treatment of hazardous waste
- Other hazardous waste treatment requirements (e.g., land disposal restrictions)
- Air pollution requirements
- DDESB safety requirements
- Other applicable Federal statutes such as the Endangered Species Act, the Native Americans Graves Protection and Repatriation Act, and the National Historic Preservation Act

This handbook does not present a comprehensive listing of these requirements. Chapter 2 of this handbook provides an overview of regulatory structures. Chapter 6 presents an overview of the DDESB safety requirements.

7.4.6 <u>Identification of Remedial Objectives</u>

Decisions regarding cleanup have two components: the remediation goal (or cleanup standard) and the response strategy. Remediation goals were described in the discussion of PRGs (Section 7.4.6). The response strategy is the manner in which the waste will be managed (e.g., use of institutional controls, removal of waste, treatment of waste once it's removed), including the engineering or treatment technologies involved. PRGs represent the first step in determining the cleanup standard. PRGs are revised as new information is gathered and will be a central part of final

[120] 40 CFR Section 300.400(g), National Oil and Hazardous Substances Pollution Contingency Plan.

cleanup decisions. It is equally important to identify potential cleanup technologies early in the process so that information required to assess the appropriate technology can be obtained during the investigation process (i.e., site findings affecting treatment selection).

The final step in planning the investigation is therefore identifying remedial objectives. What kind of cleanup activities do you anticipate? Like the PRGs and the CSM, this is a working hypothesis of what you will find (which may change later), the volume of material that you must deal with, the media with which it will be associated (if it is explosive residue), and the nature of the technology that will be used to conduct the cleanup. Early screening of alternatives to establish remedial action objectives is important. Identifying appropriate alternatives may direct the geophysical investigations to help determine if a particular technology, such as bioremediation, will work at the site. Chapter 4 has a substantial discussion of MEC detection technologies.

Finally, in addressing remedial objectives at the site, you will want to consider the disposal options for what may be an enormous amount of nonexplosive material. Typical range clearance activities excavate tons of trash and fragments of ordnance. In addition, open burning or detonation will leave additional potentially contaminated materials and media to be disposed of. Some of the trash, such as target practice material, may be contaminated with hazardous waste. Some of the metal fragments may be appropriate for recycling. Information collected during the investigation will be used to assess not only the treatment and the potential for recycling of explosive and nonexplosive residue, but also the disposal of other contaminated materials and media from the site.

7.4.7 The Data Quality Objectives of the Investigation

7.4.7.1 *Developing DQOs*

You now have the information necessary to develop the data quality objectives of the investigation. The DQOs will reflect the information that you require to achieve the decision goals identified at the beginning of the planning phase. DQOs are based on gaps in the data needed to make your decision. They should be as narrow and specific as possible and should reflect the certainty required for each step of the investigation. Objective statements that are carefully crafted, with regulator involvement and community review, will help ensure that discussions at the end of the investigation are about the risk management decisions, not about the relevance or quality of the data.

DoD/EPA Interim Final Management Principles on DQOs

Site-specific data quality objectives (DQOs) and QA/QC approaches, developed through a process of close and meaningful cooperation among the various governmental departments and agencies involved at a given military range , are necessary to define the nature, quality, and quantity of information required to characterize each military range and to select appropriate response actions.

Examples of typical DQOs may include the following:

- Determine the outer boundaries of potential UXO contamination on a range within plus or minus ___ feet.
- Determine, with ___ percent probability of detection at ___ percent confidence level, the amount of UXO found in the top 2 feet of soil.

- Verify that there are no buried munitions pits under the range (___ percent probability of detection, ___ percent confidence level).
- Determine with __ percent certainty if there is UXO in the sediments that form the river bottom.
- Determine the direction of groundwater flow with ___ percent certainty.

The DQOs for your site will determine the amount and quality of data required, as well as the level of certainty required. Which statements are appropriate for your site will depend on the previously identified goals of the investigation, the information that is already known about the site, and the acceptable levels of uncertainty.

7.4.7.2 *Planning for Uncertainty*

To a significant degree, data quality objectives will depend on the project team's and the public's tolerance for uncertainty. Ultimately, the amount of uncertainty that is acceptable, although expressed in quantitative terms, is a qualitative judgment that must be made by all of the involved parties acting together. For example, it may be possible to quantify the probability that a detector can find subsurface anomalies. However, that probability will be less than 100 percent. The acceptability of a given probability of detection (e.g., 85 percent or 60 percent) will depend on a qualitative judgment based on the decision to be made.

As in any subsurface investigation, it is impossible to resolve all uncertainties. For example, regardless of the resources expended on an investigation, it is not possible to identify 100 percent of MEC on an MRS. Likewise, unless the entire range is dug up, it is often impossible to prove with 100 percent certainty that the land area is clean and that no MEC is present. The project team will need to decide whether uncertainties in the investigation are to be reduced, mitigated, or deemed acceptable. Planned land use is an important factor in determining the acceptable level of uncertainty. Some uncertainties may be more acceptable if the military will continue to control the land and monitor the site than if the site is to be transferred to outside ownership.

Uncertainties can be reduced through process design, such as a thorough sampling strategy, and through the use of stringent data quality acceptance procedures. Uncertainties can also be reduced by planning for contingencies during the course of investigation. For example, it may be possible to develop decision rules for the investigation that recognize uncertainties and identify actions that will be taken if the investigation finds something. A decision rule might say that if X is found, then Y happens. (In the simplest example, if any anomalies excavated prove to be ordnance related, either ordnance fragments or UXO, then a more intensive sampling process will be initiated.)

The results of uncertainties can be mitigated in a variety of ways, including by monitoring and contingency planning. A situation in which some uncertainties were mitigated occurred at Fort Ritchie Army Garrison, a BRAC facility. MEC contamination was suspected beneath buildings that were constructed decades ago and were located on property designated for residential development. Because the buildings were to be reused following the land transfer, regulators chose not to require an investigation beneath the buildings because it would have necessitated razing them. As a risk management procedure, legal restrictions were established to ensure Army supervision of any future demolition of these buildings. The presence of MEC under buildings on land slated for transfer is an uncertainty the project team at Fort Ritchie chose to accept. Risks are mitigated through the use of institutional controls.

Finally, uncertainties in the investigation may be deemed acceptable if they will be insignificant to the final decision. Information collected to "characterize the site" should be considered complete when there is sufficient information to determine the extent of contamination, and the proposed response depth and the appropriate remedial technology. If information has been collected that makes it clear that action will be required, it may not be necessary to fully understand the boundaries of the range or the density or distribution of MEC prior to making the remediation decision and starting response activities. Some amount of uncertainty will be acceptable, since the information required will be obtained during the response operation. (Note: This scenario assumes that there is sufficient information both for safety planning and for estimating the costs of the remediation.)

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

American Society for Testing and Materials. ***Standard Guide for Developing Conceptual Site Models for Contaminated Sites***. Guide E1689-95; 2001.

Interstate Technology and Regulatory Council, ***Technical/Regulatory Guidelines, Munitions Response Historical Records Review***, November 2003.

Information Sources

Joint UXO Coordination Office (JUXOCO)
10221 Burbeck Road, Suite 430
Fort Belvoir, VA 22060-5806
Tel: (703) 704-1090
Fax: (703) 704-2074
http://www.denix.osd.mil/UXOCMEC**U.S. Army Corps of Engineers**

U.S. Army Engineering and Support Center Ordnance and Explosives Mandatory Center of Expertise
P.O. Box 1600
4820 University Square
Huntsville, AL 35807-4301
http://www.hnd.usace.army.mil/

Department of Defense Explosives Safety Board (DDESB)
2461 Eisenhower Avenue
Alexandria, VA 22331-0600
Fax: (703) 325-6227
http://www.ddesb.pentagon.mil

U.S. Environmental Protection Agency
Superfund Risk Assessment
http://www.epa.gov/superfund/programs/risk/index.htm

Guidance Documents

U.S. Army Corps of Engineers. ***Conceptual Site Models for Ordnance and Explosives (MEC) and Hazardous, Toxic, and Radioactive Waste (HTRW) Projects***. Engineer Manual. EM 1110-1-1200, Feb. 3, 2003.

U.S. Army Corps of Engineers. ***Technical Project Planning (TPP) Process***. Engineer Manual 200-1-2; Aug. 31, 1998.

U.S. Department of Defense. ***DoD Ammunition and Explosives Safety Standards***. DoD 6055.9-STD; July 1999.

U.S. EPA (Environmental Protection Agency). ***Compliance with Other Laws (Vols 1 & 2)***. Aug. 8, 1988.

U.S. EPA. ***EPA Guidance for Quality Assurance Project Plans***. EPA QA/G-5, Feb. 1998.

U.S. EPA. ***Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA***. Interim Final. NTIS No. PB89-184626; Oct. 1989.

Sources of Data for Historical Investigations

Air Photographics, Inc.
(aerial photographs)
Route 4, Box 500
Martinsburg, WV 25401
Tel: (800) 624-8993
Fax: (304) 267-0918
e-mail: info@airphotographics.com
http://www.airphotographics.com

Environmental Data Resources, Inc.
(aerial photographs; city directories; insurance, wetlands, flood plain, and topographical maps)
3530 Post Road
Southport, CT 06490
Tel: (800) 352-0050
http://www.edrnet.com

National Archives and Records Administration National Cartographic and Architectural Branch
College Park, MD
http://www.nara.gov

National Exposure Research Laboratory
Environmental Photographic Interpretation Center (EPIC)
U.S. Environmental Protection Agency
Landscape Ecology Branch
12201 Sunrise Drive
555 National Center
Reston, VA 20192Tel: (703) 648-4288
Fax: (703) 648-4290
http://www.epa.gov/nerlesd1/land-sci/epic/aboutepic.htm

U.S. Department of Agriculture, Natural Resources Conservation Service
(national, regional, and some state and local data and maps of plants, soils, water and climate, watershed boundaries, wetlands, land cover, water quality, and other parameters)
14th and Independence Avenue
Washington, DC 20250
http://www.nrcs.usda.gov/

U.S. Geological Survey, EROS Data Center
(satellite images, aerial photographs, and topographic maps)
Customer Services
47914 252nd Street
Sioux Falls, SD 57198-0001
Tel: (800) 252-4547
Tel: (605) 594-6151
Fax: (605) 594-6589
e-mail: custserv@edcmail.cr.usgs.gov
http://edc.usgs.gov/

Repositories of Explosive Mishap Reports

U.S. Air Force
Air Force Safety Center
HQ AFSC/JA
9700 G Avenue SE
Kirtland AFB, NM 87117-5670
Tel: (505) 846-1193
Fax: (505) 853-5798

U.S. Army
U.S. Army Safety Center
5th Avenue, Bldg. 4905
Fort Rucker, AL 36362-5363

U.S. Army Technical Center for Explosives Safety
(maintains a database of explosives accidents)
Attn: SIOAC-ESL, Building 35
1C Tree Road
McAlester, OK 74501-9053
e-mail: sioac-esl@dac-emh2.army.7-28mil
http://www.dac.army.mil/esmam/default.htm

U.S. Navy
Commander, Naval Safety Center
Naval Air Station Norfolk
375 A Street, Code 03
Norfolk, VA 23511
Tel: (757) 444-3520
http://www.safetycenter.navy.mil/

8.0 DEVISING INVESTIGATION AND RESPONSE STRATEGIES

The previous chapter provided a framework for organizing what is currently known about a site so that a project team can systematically identify the goals and objectives of an investigation. The focus of this chapter is to identify geophysical and munitions constituents sampling, analysis, and response strategies that will meet those goals and objectives.

The discussion that follows outlines major considerations in the development of your investigation and response plan. Keep in mind, however, that the foundation of your sampling and analysis plan rests on your conceptual site model (see Chapter 7).

Developing the geophysical investigation is often the most difficult part of the MEC investigation. Given the size of the ranges and the costs involved in investigating and removing MEC, judgments of acceptable levels of uncertainty often come into conflict with practical cost considerations when determining the extent of the field investigation.

Sampling and measurement errors in locating MEC on your MRS will come from several sources:

- Inadequacy of geophysical detection methods to locate and correctly identify anomalies that may be potential MEC
- Inappropriate extrapolation of the results of statistical geophysical sampling to larger areas
- Difficulty in collecting representative soil samples for munitions constituents
- Measurement errors introduced in laboratory analysis of soil samples (either on-site or off-site), including subsampling and analysis

Given that no subsurface investigation technique can eliminate all uncertainty, the sampling design (and supporting laboratory analysis) should be structured to account for the measurement error and to ensure that the data collected are of a known quality.

Field sampling activities include the following basic considerations:

- Explosives safety concerns, safety planning, and Explosives Safety Submissions (see Chapter 6)
- Detection technologies that are matched to the characteristics of the site and the UXO and to the objectives of the investigation (see Chapter 4)
- Specification of QA/QC measurements
- Determination of the quantity and quality of data needed and data acceptance criteria
- Determination of how, when, and where data will be collected
- Appropriate use of field analysis and fixed laboratory analysis to screen for explosive residues

There are typically four types of data collection methods employed during UXO investigations:

- Nonintrusive identification of anomalies using surface-based detection equipment

- Intrusive excavation of anomalies (usually to verify the results of geophysical investigations)
- Soil sampling for potential munition constituents
- Environmental sampling to establish the basic geophysical characteristics of the site (e.g., stratigraphy, groundwater depth and flow), including background levels

The following decisions are to be made when designing the data collection plan:

- Establishment of your desired level of confidence in the capabilities of subsurface detection techniques
- How to phase the investigation so that data collected in one phase can be used to plan subsequent phases
- Establishment of decision rules for addressing shifts in investigation techniques determined by field information
- The degree to which statistical sampling methods are used to estimate potential future risks
- How to verify data obtained through the application of statistical sampling approaches
- The types of field analytical methods that should be used to test for explosive residues
- The appropriate means of separating and storing waste from the investigation
- Information required for the Explosives Safety Submission

The design of the sampling and analysis effort usually includes one or more iterations of geophysical studies, which incorporate geophysical survey data processing and anomaly investigation to obtain a level of precision that will help you achieve your project objectives. Depending on your project objectives, more extensive geophysical studies may be necessary to evaluate the potential for MEC impacts at the site. For example, if your project objective is to confirm that an area is "clean" (free from MEC), and you detect a MEC item during your first geophysical sweep of the ground surface, you can conclude that the area should not be considered clean and you must modify your objective. However, no additional geophysical data collection is necessary at that point.

Conversely, your objective may be to cleanup a target area that is expected to contain artillery items (e.g., 105 mm projectiles) using the combination of detection tools and data processing techniques deemed appropriate to the site and the objective specified by your project team. However, initial excavations reveal the presence of much smaller munitions (e.g., 40 mm anti-aircraft projectiles), in addition to the artillery items. You may have to modify your geophysical detection processes in order to address this unanticipated type of munition, which will be more difficult to detect.

The design of the sampling and analysis effort should recognize that fieldwork takes place in stages. The first stage will often be a surface response effort to render the MRA/MRSs under investigation safe for geophysical investigation. The second stage will field test the detection technologies that you plan to use to verify QA/QC measurement criteria and establish a known level of precision in the investigation. The subsequent stage will involve the iterative geophysical studies discussed above. Observations in the field could cause a redirection of the sampling activities.

The bullets and discussion below address five important elements of the design of the sampling and analysis effort:

- Selection of munitions detection technologies
- Operational analysis of the munitions activities that took place at the site
- Selection of the methodology for determining the location and amount of both intrusive and nonintrusive sampling
- Development of QA/QC measures for your sampling strategy
- Use of both fixed lab and field screening analytical techniques for sampling for munition constituents

8.1 Identification of Appropriate Detection Technologies

Selection of the appropriate detection technology is not an easy task, as there is not one best tool that has the greatest effectiveness, ease of implementation, and cost-effectiveness in every situation. Rather, a combination of systems that includes sensors, data processing systems, and operational platforms should be configured to meet the site-specific conditions. The project team should develop a process to identify the best system for the particular site.

The site-specific factors affecting the selection of appropriate technologies include the following:

- The ultimate goals of the investigation and the level of certainty required for MEC detection
- The amount and quality of historical information available about the site
- The nature of the MEC anticipated to be found on-site, including its material makeup and the depth at which it is expected to be found
- Background materials or geological, topographical, or vegetative factors that may interfere with MEC detection

Site-specific information should be used with information about the different detection systems (see Chapter 4) to select the system most appropriate for the project. Three key factors in selecting a detection technology are effectiveness, ease of implementation, and cost.

The **effectiveness** of a system may be measured by its proven ability to achieve detection objectives. Measures of effectiveness include probability of detection, maximum depth of detection, false positive ("false alarm") rate, and sensor data characteristics such as signal and noise. The science of ordnance and explosives detection has improved significantly over the past decade; however, the limited ability to discriminate between ordnance and non-ordnance remains a serious deficiency. (See Chapter 4 for a discussion of detection systems.)

The **ease of implementation**, although a characteristic of the technology, is influenced by the project requirements. For example, a towed operational platform (typically a multisensor array towed behind a vehicle) may not be implementable in mountainous and rocky terrain. For another site, implementability might mean that a single detection system has to work on all types of terrain because of budgetary or other constraints.

Detection system **costs** generally depend on the operational platform and the data processing requirements. For example, hardware costs are higher for an airborne platform than for a land-based system, but an airborne platform can survey a site much faster than a land-based system, thus reducing the cost per acre. Similarly, digital georeferencing systems cost more than a GIS that can be used to manually calculate the position of anomalies, but the time saved by digitally georeferencing anomaly position data, and the associated potential reduction in errors, may speed the process and save money in the end.

8.2 UXO Detection Methods

Until the Jefferson Proving Ground Technology Demonstration (JPGTD) Project was established in 1994 to advance the state of munition detection, classification, and removal, "Mag and Flag" had been the default MEC detection method, with only marginal improvement in its detection and identification capabilities since World War II. Using Mag and Flag, an operator responds to audible or visible signals representing anomalies as detected by a hand-held magnetometer (or other detection device such as an EM instrument), and places flags into the ground corresponding to the locations where signals were produced. While Mag and Flag has improved with advances in magnetometry, it produces higher false alarm rates than other available technologies. This is particularly true in areas with high background levels of ferrous metals. In addition, the Mag and Flag system is highly dependent on the capabilities of the operator. Efficiency and effectiveness have been shown to trail off at the end of the day with operator fatigue or when the operator is trying to cover a large area quickly. Because the data from a Mag and Flag operation are not digitally recorded, it is more difficult to replicate and verify the data. This lack of digital recording also makes it difficult to assess whether an area has been completely surveyed using this technique. The certainty of the actual location of the anomaly is highly dependent on the operator's proficiency as well as on the systemic errors associated with the technique. Because of these limitations and the availability of more reliable systems, the use of Mag and Flag is decreasing. However, under certain conditions, such as very difficult terrain (e.g., mountainous, densely forested), Mag and Flag may be the most cost-effective method for detecting UXO.

What Is the Effectiveness Rate of MEC Detection Using Existing Technologies?

The answer to this question is centered around the definition of "detection." Debates over the answer to this apparently simple question reflect underlying values about how to conduct a UXO investigation and what costs are "worthwhile" to incur.

UXO objects are "seen" as underground anomalies that must be interpreted. It is often difficult to distinguish between UXO, fragments of MEC, other metallic objects, and magnetic rocks, boulders, and other underground formations. This inability to discriminate, and the resulting high number of false positives, is a contributing factor to the high cost of UXO clearance. The overall effectiveness of a detection technology is intrinsically tied to the ability of the sensor to discriminate between munitions items and other subsurface anomalies. The more sensitive the detector, the more anomalies are found. Finding the balance between reducing false alarms and ensuring that hazardous items are found is the key to a cost effective investigation.

DoD/EPA Interim Final Management Principles on UXO Detection

The critical metrics for the evaluation of the performance of a detection technology are the probabilities of detection and false alarms. Identifying only one of these measures yields ill-defined capability. Of the two, probability of detection is a paramount consideration in selecting a UXO detection technology.

Under the JPGTD program, developers test and analyze UXO detection technologies such as magnetometry, electromagnetic induction, ground penetrating radar, and multisensor systems. Emerging technologies such as infrared, seismic, synthetic aperture radar, and others are tested and developed at JPGTD. A discussion of different technologies is provided in Chapter 4.

Although many detection technologies do an adequate job of responding to the presence of metallic items below the ground surface, they may also (depending on site conditions and the type of detection technology) respond to geologic anomaly sources, such as ferrous rocks. One class of false positives is the response of sensors to nonmetallic sources. In addition, currently available technologies do not discriminate between metallic items of concern (i.e., UXO and buried munitions), fragmentation from exploded munitions, and non-ordnance-related metal waste. These false positive anomalies from geologic sources and non-ordnance related metallic items can greatly increase the number of anomaly excavations that must be undertaken during investigations and remedial responses, as well as during QA/QC of these activities. Development of reliable means of distinguishing between ordnance items and other subsurface anomaly sources will minimize false positives and, therefore, reduce the cost and time needed for a project.

In an attempt to address this issue, Phase IV of the JPGTD was initiated with the primary goal of improving the ability to distinguish between ordnance and nonordnance. Although progress has been made in distinguishing UXO from clutter such as UXO fragments, additional work is still needed to further advance target discrimination technologies, to make them commercially available, and to increase their use. With reliable and readily available target discrimination technologies, the number of false positives should be greatly reduced, thereby significantly reducing the costs of UXO investigations.

A number of data processing and modeling tools have been developed to screen munitions targets from raw detection data. These discrimination methods are typically based on one of two approaches. One approach is to rely on a comparison of the signatures of potential targets against a database of known UXO (with a variety of sizes, shapes, depths, and orientations) and clutter signatures. A more effective approach is to model the expected geophsysical signals based on the physics of the sensor and its expected response to the item being searched for. Additional information about data processing for UXO discrimination is provided in Chapter 4.

Identifying UXO Locations

In the past, the primary method used by UXO personnel to identify the location of anomalies was to manually mark or flag the locations at which UXO detection tools produced a signal indicating the presence of an anomaly. If operators wished to record the UXO location data, they would use GIS or other geographic programs to calculate the UTM (Universal Transverse Mercator) grid coordinates for each flag. Since the development of automatic data-recording devices and digital georeference systems, data quality has improved significantly. Using digital geophysical mapping, a UXO detection device identifies the anomaly, and a differential global positioning system locates the position of the anomaly on the earth's surface. The accuracy of the positional data depends upon site conditions such as vegetative cover that could interfere with the GPS satellite. Under ideal conditions, however, the differential GPS can be accurate to within several centimeters. The data are then merged and the location of each anomaly is recorded. Therefore, flags are not needed to record and find the location of the UXO. Because digital geophysical mapping records location data automatically, the risk of an operator missing or misrecording a location, as occurs when operators manually record anomaly locations based on analog signals, is minimized, and the data can be made available for future investigations and for further data processing. However, the potential exists for analyst errors in the merging of the anomaly and positional data. Therefore, anomaly reacquisition is used to verify the field data. Section 8.3.1.5 discusses anomaly reacquisition, and Section 4.2.3.1 describes the application of positioning technologies to geophysical data collection.

DoD/EPA Interim Final Management Principles on Data Recording

A permanent record of the data gathered to characterize a site and a clear audit trail of pertinent data analysis and resulting decisions and actions are required. To the maximum extent practicable, the permanent record shall include sensor data that is digitally recorded and georeferenced. Exceptions to the collection of sensor data that is digitally recorded and georeferenced should be limited primarily to emergency response actions or cases where their use is impracticable. The permanent record shall be included in the Administrative Record. Appropriate notification regarding the availability of this information shall be made.

8.3 Methodologies for Identifying Munitions Response Areas

The next key element of your investigation will be to select the quantity and location of samples. In reality, there are three questions to be answered:

- Where to deploy your detection equipment
- Where and how many anomalies are to be excavated to see what you have actually found
- How to use the information from detection, anomaly reacquisition, and

Terms Used in MEC Sampling

Because many familiar terms are used in slightly different ways in the discussion of statistical sampling, the following definitions are provided for clarification:

Detection – Determining the presence of geophysical anomalies targets from system responses (UXO Center of Excellence Glossary, 2000).

Discrimination – Distinguishing the presence of UXO from non-UXO from system responses or post-processing.

Sampling – The act of investigating a given area to determine the presence of UXO. It may encompass both the nonintrusive detection of surface and subsurface anomalies and excavation of anomalies.

Location – Determination of the precise geographic position of detected UXO. Includes actions to map locations of detected UXO. (UXO Center of Excellence Glossary, 2000).

Recovery – Removal of UXO from the location where detected (UXO Center of Excellence Glossary, 2000).

Identification/evaluation – Determination of the specific type, characteristics, hazards, and present condition of UXO (UXO Center of Excellence Glossary, 2000).

excavation to make a decision at your site

Two methodologies have been developed to answer these questions – CSM-based and statistically based sampling. The two methods are discussed in the following sections. It is important to remember that the methods are not mutually exclusive, but can be used together to characterize the ordnance at your site.

8.3.1 CSM-Based Sampling Design

Your sampling design will be driven by your CSM (and the historical information gathered to support your CSM), the purpose of the investigation, and the terrain being investigated. In the simplest terms, two functional purposes affect the nature of your sampling design:

- Purpose 1— search for munitions response sites (e.g., a target area) to determine the possible location of munitions and the need for and location of further investigation.
- Purpose 2 — establish boundaries for and further characterize (e.g., ordnance type, depth) the sites where munitions have been located to guide the risk management decision that will lead to removal or remediation of the munitions.

Two types of geophysical survey patterns can be used to meet these two sampling purposes:

- Transects take a one-dimensional “slice” of a sampling area, the width of which is the width of the geophysical sensor.
- Grids, or 100% surveys, consist of overlapping, parallel transects that are used to create a two-dimensional map of a small, defined sampling area.

The following sections describe how and when these two patterns can be applied to accomplish the two different sampling purposes.

8.3.1.1 *Searching for Munitions Response Areas*

Regularly spaced parallel transects can be used to efficiently search a large area for evidence of concentrated areas of UXO. This approach can be especially useful to determine the location of target areas within a known or suspected firing range, and knowledge of the weapons systems used on the range can be used to determine appropriate search transect spacing. Field manuals for each weapon system are maintained and provide the expected high medium and low distribution of impact around targets under normal operating conditions. This information can be used to calculate spacing between parallel transects that will allow for less than 100 percent sampling and provide confidence that evidence of an impact area such as munitions fragments or UXO can be located. Figure 8-1 illustrates an example of a search using transect sampling.

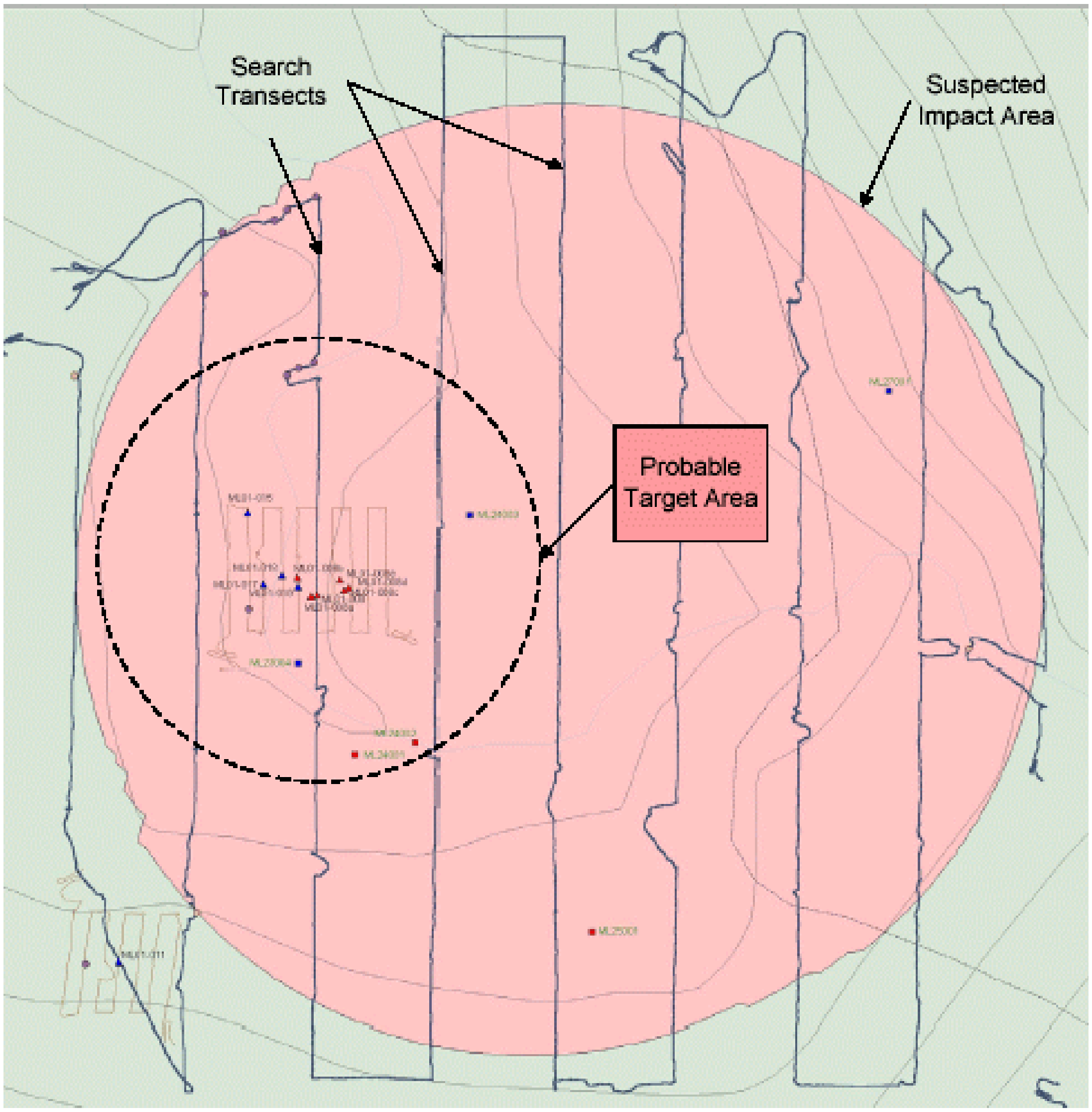

Figure 8-1. Example of Search Transects

Transect-Based Searches for Target Areas: Adak Island, Alaska

While planning the remedial investigation of Adak, the project team was faced with the issue of adequately investigating several large combat ranges (between approximately 3,400 and 6,800 acres). These areas were designated as combat ranges in June of 1943, during the time that much of Adak was in use as a training area for World War II troops preparing to retake the island of Kiska from the Japanese. Preliminary site investigation results provided evidence that at least some of the ranges had been used for live-fire 60 mm and 81 mm mortar training. The objective of the project team was to develop an investigation approach that would be cost-effective while still providing confidence that any target areas likely to contain UXO had been located.

The project team decided that a systematic search of the combat ranges using parallel transects would meet the investigation objectives. An operational analysis of the weapon systems of concern was undertaken to determine the spacing of these parallel transects. This analysis consisted of creating a "model" of the impacts that would result from small-scale target practice, based on information contained in Army field manuals for the weapon systems. Information from the field manuals was also used to determine the radius around an impact that would contain fragmentation of sufficient quantity to be detected by the geophysical sensor. This information was combined to estimate the minimum dimensions of potential target areas. The recommended spacing between the parallel transects was set at 75 percent of these minimum dimensions in order to obtain certainty that a transect would traverse any target areas.[1]

One of the key features of this approach was the agreement by the project team that fragmentation provided evidence of potential target areas and that areas in which fragmentation was located warranted further investigation, even if no UXO was found during the initial parallel transect search. This allowed the team to feel confident that the majority of the combat ranges could be designated for no further action upon the completion of the remedial investigation. The approach also located several previously unknown target areas, as well as an undocumented ordnance disposal area.

[1]Conceptual Site Model-Based Sampling Design, the UXO Countermine Forum 2001.

Use of a grid pattern when performing a search is appropriate when the primary release mechanism indicated by the CSM is loss/abandonment or unsanctioned burial (e.g., at firing points, bivouac/encampment areas, and transfer points), and the area of the search is relatively small (see Figure 8-2). In this case, the location and size of the grid should be determined from site reconnaissance information and knowledge of past ordnance activities (e.g., unsanctioned burials may have occurred near firing points). The lane spacing of the grid survey should be based on the sensor being used, the expected depth, and the size of the expected ordnance type, and should be influenced by the results of the geophysical prove-out.

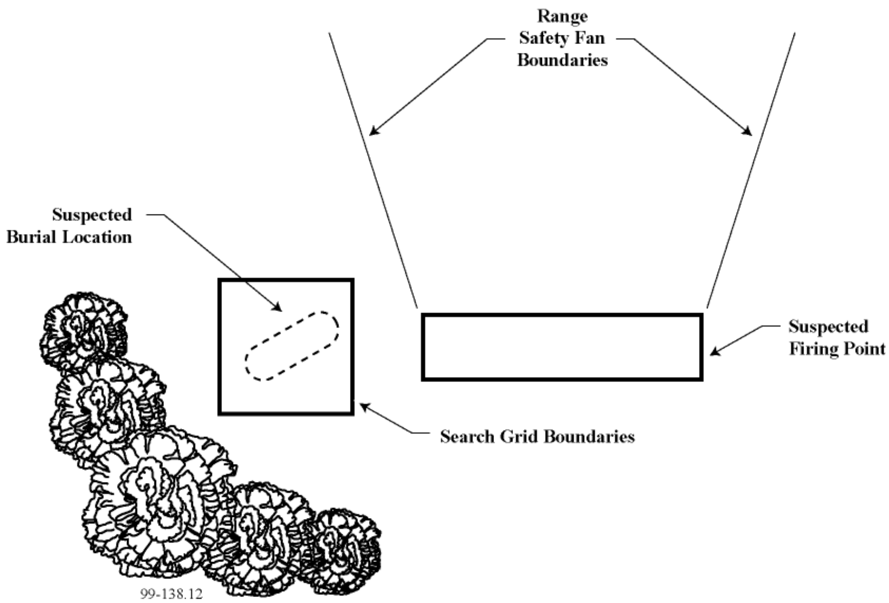

Figure 8-2. Example of a Sample Grid

8.3.1.2 *Boundary Delineation and Characterization of Munitions Response Areas*

Either parallel transects or the grid pattern may be used when the purpose of the sampling is to bound and characterize an area. For example, the boundaries of a target area may be estimated either from closely spaced transects (on the order of 5-15 meters), or from the geophysical map produced from a grid-based survey of the area. The selection of the pattern will depend, in part, on the terrain and vegetation of the area, the known or suspected types of ordnance in the sampling area, and the DQOs for the sampling effort.

8.3.1.3 *Site Conditions and Geophysical Sensor Capabilities*

In addition to the two sampling purposes discussed above, site conditions will also play a role in the selection of the sampling pattern. If the site terrain is open and relatively flat, a grid-based sampling pattern can be very effective. (If your purpose is to search for UXO, it may be more effective to start out with a transect-based design.) A transect-based design may also be more effective if the terrain is heavily wooded or sloping, (e.g., by reducing the need for brush clearing), regardless of the purpose of the sampling effort.

The site-specific capability of the geophysical sensor will also affect sample design. Site conditions that lead to greater uncertainty in the performance of the sensor (e.g., very rough terrain leading to noisy geophysical sensor data) may be a reason to increase the amount of surveying that is done, whether by decreasing the distance between parallel transects or by increasing the overlap between adjacent transects in a grid pattern.

8.3.1.4 *Anomaly Identification and Prioritization*

After the survey has been completed, the geophysical and positional data are processed and analyzed to identify and locate geophysical anomalies that may be MEC (see Chapter 4 for a discussion of the anomaly identification process). The outputs from this process, often called a "dig list," are the locations, signal amplitudes, and estimated depths of the sources of the anomalies. On many sites, the anomalies included on the dig list are prioritized based on the geophysical analyst's judgments about which anomalies are most likely to be caused by subsurface ordnance items. This prioritization process is often an ad hoc form of anomaly discrimination, based on the analyst's general and site-specific experience (see the discussion in Section 8.2). The effectiveness of this prioritization depends on whether or not information from a geophysical prove-out has been used successfully to inform the prioritization process, and whether the analyst is receiving and using feedback from the anomaly excavation results.

Use of a prioritized dig list can increase the efficiency of the anomaly excavation process by focusing the excavation efforts on the anomalies most likely to be of interest. However, a sample of all anomalies that meet threshold criteria for identification (even those judged not likely to be ordnance) should be excavated in order to provide information about the effectiveness of the prioritization process.

8.3.1.5 *Anomaly Reacquisition*

In general, before an anomaly is excavated, its location will be "reacquired" by the anomaly excavation team. The accuracy of anomaly locations entered on dig lists depends on both the survey pattern and the accuracy of the positioning system used during the geophysical survey. Therefore, the search radius used during anomaly reacquisition is another parameter that must be considered during the development of the sampling methodology.

In general, the locations of anomalies identified from a grid survey will be more accurate than those identified from a transect survey. This is because multiple passes of the geophysical detector over or near an anomaly source will give the analyst more data to use to estimate its location. And although differential global positioning system (DGPS) will provide the most accurate positional data, site conditions (especially dense tree canopy) may preclude the use of this system, and less accurate positioning methods may need to be used. All of these issues should be considered when specifying the search radius to be used during anomaly reacquisition.

The other factor to consider is the geophysical sensor used to reacquire the anomaly positions. Ideally, this will be the same device that was used to perform the original geophysical survey. However, logistical circumstances may not make it possible to use the same device (for example, the qualified geophysical survey personnel may have already left the site by the time anomaly excavation is undertaken). In this case, the excavation team may use a hand-held sensor to reacquire anomaly locations. It is important that this hand-held sensor be of the same type (magnetometer or electromagnetic) as the sensor originally used to perform the survey.

8.3.2 Use of Statistically Based Methodologies To Identify UXO

Given the variation in the size of the ranges investigated, a variety of statistical sampling approaches have also been used to investigate MRS/MRAs.

This section addresses four topics pertinent to statistically based sampling: the rationale for statistical sampling, how DoD currently uses the data from such sampling programs, regulator concerns with the use of statistically based data, and recommendations on appropriate use of these data to make appropriate closure decisions for a range.

8.3.2.1 *Rationale for Statistical Sampling*

Statistically based sampling was developed to address the limitations of noninvasive UXO detection technologies and the use of those technologies on the large land areas that may make up a range. Current methodologies for identifying anomalies in a suspected UXO area have various limiting deficiencies, as described previously. The most common deficiencies include low probability of detection and low ability to differentiate between UXO and/or fragments and background interference (objects or natural material not related to ordnance). Thus, most detection technologies have a moderate to high false alarm rate. This means that there is a high degree of uncertainty associated with the data generated by the various detection methods. No analogous situation exists for identifying compounds usually found at conventional hazardous waste sites. The problem of highly uncertain anomaly data is magnified for three reasons:

- The areas suspected of containing UXO could be hundreds or even thousands of acres; therefore, it is often not practicable to deploy detection equipment over the entire area.
- Even within sectors suspected of containing UXO, it is often not practicable to excavate all detected anomalies during sampling to confirm whether they are in fact UXO. Excavation to the level appropriate for the future land use is normally done during the remediation phase.
- When detection tools detect anomalies in areas where it is not known if ordnance has been used, it is difficult to know (in the absence of excavation) if the detected anomaly is in fact ordnance.

Statistically based sampling methods were developed to address the issue of how to effectively characterize a range area without conducting either nonintrusive detection or intrusive sampling on 100 percent of the land area. Statistically based sampling methods extrapolate the results of small sample areas to larger areas.

8.3.2.2 *Historical Use of Statistical Sampling Tools*

A variety of statistical sampling methodologies exist, each serving a different purpose, and each with its own strengths and weaknesses. The two common statistical sampling tools historically used by DoD are SiteStats/GridStats and the UXO Calculator. The general principles of the two approaches are similar. First, the sector is evaluated to determine if it is homogeneous. If it is not homogeneous, a subsector is then evaluated for homogeneity, and so forth, until the area to be investigated is determined to be homogeneous. The sampling area is divided into a series of grids and detection devices used to identify subsurface anomalies. The software, using an underlying probability distribution, randomly generates the location and number of subsequent samples within a grid, or the user can select the location of subsequent samples. Based on the results of each dig, the model determines which and how many additional anomalies to excavate, when to move on to the next grid, and when enough information is known to characterize the grid. (See the following text box for a discussion of homogeneity.)

The Importance of Homogeneity

The applicability of statistical sampling depends on whether the sector being sampled is representative of the larger site. Statistical sampling as incorporated in SiteStats/GridStats and UXO Calculator assumes that a sector is homogeneous in terms of the likelihood of UXO being present, the past and future land uses, the types of munitions used and likely to be found, the depths at which UXO is suspected, and the soils and geology. Because statistical sampling assumes an equal probability of detecting UXO in one location as in another, if the distribution of UXO is not truly homogeneous, the sampling methodologies could overlook UXO items. Environmental conditions such as soils and geology affect the depth and orientation at which munitions land on or beneath the ground surface. If, on one part of a range, munitions hit bedrock within a few inches of the ground surface, they will be much closer to the surface (and probably easier to detect) than others that hit sandy soil on top of deeper bedrock. In addition, different types and sizes of munitions reach greater depths beneath the surface.

Attempts to assess homogeneity can include, but should not be limited to, the following activities: conducting extensive historical research about the types of munitions employed and the boundaries of the range, surveying the site, or using previously collected geophysical data.

There are two main differences between SiteStats/GridStats and the UXO Calculator. First, the technologies typically used for input differ. SiteStats/GridStats is most commonly used with a detection tool or combination of tools, whereas UXO Calculator is used with both a detection tool and a digital geophysical mapping device. Second, SiteStats/GridStats produces a UXO density estimate based only on the statistical model. The data from SiteStats/GridStats are then input into OECert, a model that contains a risk management tool as well as a screening-level estimator for the cost of remediation.[121]

The SiteStats/GridStats results are generally presented as having a confidence level that is based on a set of assumptions and may not be justified. The UXO density estimates are often used as input to OECert to evaluate the public risk and to estimate the cost of removal alternatives. The OECert model compares the costs of remediation alternatives to the number of public exposures likely under each remediation scenario. The model then develops recommendations that minimize remediation costs. The risk levels used for the recommendations are acceptable to the U.S. Army Corps of Engineers (USACE).[122]

UXO Calculator also estimates UXO density, but the program contains an additional risk management tool that allows the operator to input an assumed acceptable UXO density based on land use, assuming UXO distribution is homogeneous within a sector. UXO Calculator then calculates the number of samples required to determine if this density has been exceeded. However, acceptable UXO target densities are neither known nor approved by regulators. As with SiteStats/GridStats, the

[121]"Site/Grid Statistical Sampling Based Methodology Documentation," available at USACE website: www/hnd/usace.army.mil/oew/policy/sitestats/siteindx.htm.

[122]U.S. Army Corps of Engineers. Ordnance and Explosives Cost Effectiveness Risk Tool (OECert), Final Report (Version E), Huntsville, AL: Ordnance and Explosives Mandatory Center for Excellence, 1995.

sample size obtained is also based on an assumption of homogeneity within a sector. The UXO Calculator software contains a density estimation model, risk management tool, and cost estimator tool. The risk management tool requires assumptions about land use and from that information assumes a value for the number of people who will frequent a site. The justification of the land use assumptions and the resulting population exposure are not well documented.

Table 8-1 summarizes these two tools and their strengths and weaknesses. Table 8-2 identifies four survey patterns and summarizes their strengths, weaknesses, and applications.

Table 8-1. UXO Calculator and SiteStats/GridStats

Statistical Sampling Method	Description	Strengths and Weaknesses	Intensity of Coverage	Typical DoD Use
UXO Calculator	Determines the size of the area to be investigated in order to meet investigation goals, confidence levels in ordnance contamination predications, and UXO density in a given area.	Investigates a very small area to prove to varying levels of confidence that a site is "safe" for transfer. All computations are based on an assumption of sector homogeneity with respect to UXO distribution.	Low	Used with digital geophysical mapping data. Used to make a yes or no decision as to the presence or absence of ordnance. Used to determine confidence levels in ordnance contamination predictions.
SiteStats/ GridStats	Random sampling is based on a computer program. Usually less than 5 percent of a total site is investigated and 25 to 33 percent of anomalies detected are excavated.	Potentially huge gaps between sampling plots, very small investigation areas, no consideration of fragments or areas suspected of contamination. Relies on a rarely valid assumption that UXO contamination is uniformly distributed. Hot spots may not be identified.	Low	Designed for use with Mag and Flag data. Reduces the required amount of excavation to less than 50 percent of levels required by other techniques. Used by DoD to extrapolate results to larger area.

Table 8-2. General Summary of Statistical Geophysical Survey Patterns

Survey Patterns	Description	Strengths and Weaknesses	Intensity of Coverage	Typical DoD Use
Fixed pattern sampling	Survey conducted along evenly spaced grids. A percentage of the site (e.g., 10 percent) is investigated.	Even coverage of entire site. Gaps between plots can be minimized.	Medium	Useful for locating hot spots and for testing clean sites.
Hybrid grid sampling	Biased grids investigated in areas suspected of contamination or in areas with especially large gaps between SiteStats/GridStats sampling plots.	Compensates for some of the limitations of SiteStats/GridStats. Relies on invalid assumption that UXO contamination is uniformly distributed.	Medium	Used to direct sampling activity to make site determinations.
Transect sampling	Survey conducted along evenly spaced transects.	Used in areas with high UXO concentrations.	Medium	Useful for locating boundaries of high-density UXO areas.
Meandering path sampling	Survey conducted along a serpentine grid path through entire site using GPS and digital geophysical mapping.	Reduced distances between sampling points; environmentally benign because vegetation clearance is not required. Digital geophysical mapping records anomaly locations with improved accuracy.	Medium	Used to direct sampling activity to make site determinations in ecologically sensitive areas.

*Any of these survey patterns may include limited excavation of anomalies to verify findings.

8.3.2.3 *Regulator Concerns Regarding the Historical Use of Statistical Sampling Tools*

> **DoD/EPA Interim Final Management Principles on Statistical Sampling**
>
> Site characterization may be accomplished through a variety of methods, used individually or in concert with one another, and including, but not limited to, records searches, site visits, or actual data acquisition, such as sampling. Statistical or other mathematical analyses (e.g., models) should recognize the assumptions embedded within those analyses. Those assumptions, along with the intended uses of the analyses, should be communicated at the front end to the regulators and the communities so the results may be better understood. Statistical or other mathematical analyses should be updated to include actual site data as it becomes available.

The use of statistical sampling is a source of debate between the regulatory community (EPA and the States) and DoD.[123] Faced with large land areas requiring investigation, and the high costs of such investigation, DoD has used several statistical approaches to provide an estimate of the UXO density at a site as a basis for selecting remedies or making no-action decisions. Regulatory concerns have generally focused on four areas: (1) the inability of site personnel to demonstrate that the assumptions of statistical sampling have been met, (2) the extrapolation of statistical sampling results to a larger range area without confirmation or verification, (3) the use of the density estimates in risk algorithms to make management decisions regarding the acceptable future use of the area, and (4) the use of statistical sampling alone to make site-based decisions. Criticisms of statistical sampling have centered around the use of the statistical tools embodied in the SiteStats/GridStats, and UXO Calculator. However, some of the criticisms may be applicable to other statistical methods as well. Criticisms include the following:

- Historically, the use of statistical sampling tools has been based on assumptions that the area being sampled is homogeneous in terms of the number of anomalies, geology, topography, soils, types of munitions used and depths at which they are likely to be found, and other factors. Often, too little is known to ensure that the statistical sampling assumptions are met and the procedures used to test sector homogeneity are not effective enough to detect sector nonhomogeneity.
- Statistical procedures used in SiteStats/GridStats to determine when the sector has been sufficiently characterized and to test sector homogeneity are not statistically valid.
- In practice, statistical procedures are often overridden by ad hoc procedures; however, the subsequent analysis does not take this into account.
- The use of statistical techniques often results in the sampling of a relatively small area in comparison with the size of the total area suspected of contamination. The small sampling area may not necessarily be representative of the larger area.
- The ability of statistical sampling to identify UXO in areas where munitions activities occurred is questionable.
- The capabilities of current statistical methods to identify hot spots are limited.
- A nonconforming distribution may not be identified by the program and thus not be adequately investigated.

[123] "Interim Guidance on the Use of SiteStats/GridStats and Other Army Corps of Engineers Statistical Techniques Used to Characterize Military Ranges." Memo from James E. Woolford, Director, EPA Federal Facilities Restoration and Reuse Office, to EPA Regional Superfund National Policy Managers, January 19, 2001.

- The distances between sampling grids are often large.
- Relying exclusively on actual UXO effectively ignores UXO fragments as potential indicators of nearby UXO.
- Confidence statements based on the assumed probability distribution do not account for uncertainties in the detection data.
- Confidence statements also relate to an expected land use that is not carefully justified.
- Results of confirmatory sampling are not presented or summarized in a manner that allows a regulator to evaluate the quality and limitations of the data that are used in the risk management algorithms.
- There is no sensitivity analysis of the applicability of the risk management tools to the input parameters. For example, there is nothing analogous to EPA's "most probable," "most exposed individual," and "worst case" assumptions for baseline risk assessments at Superfund sites.
- The levels of exposure risks developed by the OECert program have not been accepted by regulators or the public.

8.3.2.4 *Recommendations on the Use of Statistical Sampling*

In general, regulatory agencies believe that statistical sampling is best used as a screening tool or to provide preliminary information that will be confirmed during the clearance process. Statistically based sampling tools, when used in conjunction with other tools, may be used for the following purposes:

- Prioritizing range areas for thorough investigation and/or clearance
- Analyzing the practicality and cost of different clearance approaches, as well as the usefulness of different remedial alternatives
- Establishing the potential costs of clearance for different land uses
- Facilitating a determination of which land uses may be appropriate following remediation, and the levels and types of institutional controls to be imposed

Regulatory agencies also believe that statistical sampling alone should not be used to make no-action decisions. Other significant data also will be required, including the following:

- Extensive historical information
- Groundtruthing (comparing the results of statistical sampling to actual site conditions) of randomly selected areas to which results will be extrapolated

Even the use of historical and groundtruth information, combined with statistical sampling results, will be suspect when the presence of ordnance fragments suggests that active range-related activities occurred in the past. Range investigation practices are evolving, but many regulatory and technical personnel agree that statistical sampling tools must be used in conjunction with the other elements of the systematic planning process (including historical research). In examining the use of statistical sampling tools, you should consider the following:

- The assumptions on which statistical sampling techniques are based should be both clearly documented and appropriate to the particular site under investigation.

- The density estimates from the statistical sampling procedure should be carefully scrutinized and computed using statistically correct algorithms.
- Any risk estimates based on computer algorithms (e.g., OECert) should be adequately documented for regulatory review.

Given the size of many MRAs, it is likely that some form of statistical sampling will be used at your site. Decisions regarding the acceptability of statistical sampling involve the following issues:

- The nature of the decision to be made
- Agreement on the criteria on which the decision will be made
- Agreement on the assumptions and decision rules that are used in the statistical model
- The level of confidence in the detection technology
- The use and amount of anomaly reacquisition and excavation to verify findings of detection technology
- The presentation of these data, summarized in an appropriate format
- The quality and quantity of information from historical investigations

8.3.2.5 *Research and Development of New Statistical Sampling Tools*

The perceived ongoing need for statistical sampling has led the DoD's Strategic Environmental Research and Development Program (SERDP) to identify as high priority any projects that have the potential to develop "defensible statistical sampling schemes for bounding UXO contaminated areas." Three research projects in the MEC and UXO arena are currently under way.

Statistical Methods and Tools for UXO Site Characterization — This project will evaluate and develop statistical methods and tools that can be used for characterization and verification plans and data evaluation schemes. The development of the statistical sampling methods and tools will be consistent with the EPA's data quality objective (DQO) process. This process is used to plan any characterization activity to ensure that the right type, quantity, and quality of data are gathered to support confident decision-making. It is intended that the methods will strike an appropriate balance between the probability of missing UXO and the costs of characterization or unnecessary remediation (false positives). Statistical methods will be evaluated, adapted, or developed, and prototype tools will be developed and demonstrated. The methods will allow quick evaluation of trade-offs involving costs, risk of missing UXO, acceptable probabilities for decision errors, percentage of the site characterized or the number of swaths, false-positive error rates, grid sizes, etc. One statistical tool developed under this program is the Visual Sample Plan (VSP) software tool (developed by Pacific Northwest National Laboratory through a SERDP-sponsored project) for developing and visualizing transect survey design. The methods incorporate elements of the DQO approach for developing an optimal transect sampling design based on specified decision rules and tolerable decision error probabilities. Site-specific DQOs are specified and transect patterns (parallel, square, rectangular, or meandering) are identified and visually displayed using VSP. The VSP software is used to illustrate decision rules and associated transect sampling schemes that will provide the user's required high probability of traversing and detecting a target area of concern of specified size, shape, and anomaly (or UXO) density.

Bayesian Approach to UXO Site Characterization with Incorporation of Geophysical Information — The objective of this project is to develop a sampling protocol for estimating the intensity of UXO contamination across a site. This protocol uses an inherently Bayesian approach that allows for incorporation of historical information and geophysical data into the site characterization process. This protocol will use a sample optimization procedure to be incorporated to allow for straightforward field deployment of this characterization approach. A data worth framework will be used to optimize sampling locations and to determine when characterization is complete.

Statistical Spatial Models and Optimal Survey Design for Rapid Geophysical Characterization of UXO Sites — This project seeks to identify the mathematical foundations and statistical protocols in the domain of point process theory of spatial statistics by focusing on three objectives: (1) develop the statistical spatial models needed to produce the mathematical foundation for UXO distribution characterization, (2) develop optimal sampling strategies using experimental survey design, and (3) improve confidence levels for contamination estimates from measured data by improving discrimination techniques.

8.4 Incorporating QA/QC Measures Throughout the Investigation

Quality assurance and quality control should be incorporated into every aspect of your investigation. Begin planning for quality at the start of a project by developing DQOs and standard operating procedures (SOPs). Throughout the process, all data should be managed so as to provide an auditable trail of all data points and every geophysical anomaly detected.

The quality assurance and quality control (QA/QC) requirements for MEC investigations differ from other types of environmental investigations because of the unique characteristics of MEC and the tools available for characterizing MRSs. For example, the probability of detection when using any detection system depends on site-specific conditions; therefore, the technology and its capability (performance criteria) must be established for each site at which it will be used. You can determine the effectiveness by conducting tests of the technology on seeded areas representative of the range itself, using the sampling methods to be used in the actual investigation. Similarly, because of the complexities of operating detection systems and analyzing detection data, and the potential ramifications of mischaracterizing an area as clear, operator and analyst skills and capabilities are of paramount importance. Therefore, all personnel working on a site must be appropriately trained and qualified to work on the site using the detection system that will be used. What does not differ from other types of environmental investigations is the applicability of using a graded approach to the QA/QC of the investigation.

The resources dedicated to QA/QC should be appropriate to the kind of decision being made (e.g., preliminary screening vs. definitive determination of site response), as well as the size and complexity of the investigation. Specific QA/QC measures that could be taken include the following:

- **Development of data quality objectives** — DQOs should clearly relate to the data being collected and to the decisions being made. The DQOs should state the acceptable levels of uncertainty and provide acceptance criteria for assessing data quality.

- **Sampling and analysis plan** — The geophysical survey and the intrusive investigation should be based on a comprehensive CSM. The sampling methods should consider release mechanisms and weapons systems. All primary sources should be addressed and follow-up searches should be performed.
- **Geophysical prove-out** — The geophysical prove-out is used to select the geophysical equipment to be used. In this process, the performance of the geophysical equipment is assessed in conditions representative of the actual field conditions, sampling methods to be used, and targets likely to be encountered at specific depths. In general, the capability of the detection instruments to meet project-specific performance requirements is demonstrated in the field using geophysical prove-out sites in areas that have geology and topography similar to the area being investigated. The accuracy of this demonstration depends on the number, types, orientations, and depths of the test items buried in the prove-out site. Various metrics can be used to assess this capability, including probability of detection at a specified confidence level, maximum required detection depth, and geophsycial sensor signal and noise characteristics. Project goals may be based on any or all of these measures, and the geophysical prove-out design should support the assessment of the detection process performance against these metrics.
- **Geophysical qualification** — All members of the geophysical survey team are qualified by demonstrating their ability to meet prove-out performance results to ensure precision of geophysical data. An example of qualification for surface sweeps would be "search effectiveness probability validation," which is used to test the team and the detection equipment. In search effectiveness probability validation, the area being investigated is "salted" with controlled inert ordnance items that are flagged or collected as the sweep team proceeds through the salted area. The number of items planted collected is compared with the total number of items planted, and a percentage for search effectiveness probability is calculated.
- **Site preparation** — Prior to the geophysical survey, the site is prepared by setting survey stakes and by removing all metallic debris that could mask subsurface anomalies. In this process, all ordnance-related items found on the surface are documented and removed.
- **Geophysical survey** — The output of the geophysical survey is geophysical and positional data about subsurface anomalies encountered. The results of the survey are affected by the method used to collect positional data and by the performance of the field team. Quality control is conducted on the geophysical survey using several mechanisms: (1) confirmation of proper functioning of detectors, (2) field surveillance to confirm adherence to SOPs, and (3) independent resurvey of a portion of the area under investigation. UXO survey teams may independently perform distance or angular measurements two times to identify deviations resulting from human error. For geophysical mapping performed without digital geophysical reference systems, Universal Transverse Mercator (UTM) grid coordinate values created in GIS or other geographic programs are verified by QC teams using a differential GPS to ensure correct target locations.
- **Anomaly identification** — The merged geophysical and positional data are analyzed to identify and locate anomalies. The QC aspects of anomaly identification include accurately merging data points, incorporating feedback from intrusive investigations, and applying objective criteria to the identification process.

- **Anomaly reacquisition** — Areas in which anomalies were initially detected are reexamined, and the estimated anomaly location is flagged. This process helps to ensure the accuracy of the anomaly location and depth data.
- **Anomaly excavation** — Sources of anomalies are identified and excavated, and the cleared hole is then verified by a detector. Results are fed back into the anomaly identification process. Quality control is then conducted over the entire area to ensure that anomalies have been excavated.
- **Quality Control Program** — The contractor responsible for implementation of the investigation should have a comprehensive quality control program, including planned periodic surveillance of both field and data processing and analysis activities, as well as quality control acceptance sampling after the completion of fieldwork to confirm the adequacy of the work done.

8.5 Devising an Investigation Strategy for Munitions Constituents

This section introduces unique considerations in the design of an investigation strategy for determining the nature and extent of contamination from munitions constituents. Two aspects of the investigation strategy are discussed: the location and type of sample to be taken and methods for chemical analysis.

8.5.1 Sampling Strategy

As with a more routine hazardous waste site, the manner in which sampling is conducted represents the greatest potential for uncertainty and error to be introduced into the environmental decision process. However, increasing evidence from extensive studies by the Cold Regions Research and Engineering Laboratory (CRREL)[124] suggests that, given the extreme spatial heterogeneity of munition constituents, sampling of contaminated soils should be approached differently than the traditional hazardous waste investigation.

8.5.1.1 *Knowing Where To Sample*

A good sampling strategy should be based on a clear CSM that indicates all primary source and release mechanisms associated with each ordnance-related activity. The more you know about the ordnance activities on the site, the more representative the locations will be of ordnance-related contamination in that area of concern. Tables 7-1 through 7-6 in Chapter 7 show examples of ordnance-related activities and associated sources, release mechanisms, and expected MEC contamination. Thorough examination of historical records, aerial photographs, and base operational records will facilitate sufficient reconstruction of past ordnance-related operations. In many cases, however, design of an effective strategy for munitions constituents will depend on having the results of the MEC investigation. Confirming the location of target areas (and associated low-order detonations), firing points, and detonation areas will be a prerequisite for knowing where to sample.

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[124]T.F. Jenkins, P.G. Thorne, S. Thiboutot, G. Ampleman, and T. Ranney. *Coping with Spatial Heterogeneity Effects on Sampling and Analysis at an HMX-Contaminated Antitank Firing Range*, Field Analytical Chemistry and Technology 3(1): 19-28, 1999.

8.5.1.2 ***Collecting Soil Samples***

Recent research by CRREL suggests that composite sampling provides a more accurate depiction of soil concentrations of MC. This same research also suggests that use of field analytical techniques is beneficial in a number of respects and has a high level of agreement with the use of off-site analytical methods for measuring MC. The use of field analytical methods also has the advantage of increasing sample density and, therefore, improving sample representativeness.

The traditional approach to collecting samples for chemical analysis uses large sampling grids and a small number of discrete samples. Usually, suspect areas of sites are divided into grids with dimensions ranging from tens to hundreds of meters. This approach involves the collection of a single core sample within a grid. The sample is divided into depth intervals, which are analyzed at an off-site commercial laboratory. Contaminant concentrations obtained from discrete sample analysis are then compared with background levels and action levels established for the site to determine the need for cleanup. This approach assumes that contaminant concentrations in the samples adequately represent the average concentrations within grid boundaries.

The problem with this approach in sampling for MC contamination is the spatial heterogeneity of munitions constituents. Concentrations of MC in adjacent soil samples may vary exponentially; therefore, you may miss the presence of MC altogether if too few samples are taken or the sampling locations are not correctly placed.

Sampling for any chemical residue is affected by the spatial heterogeneity of the residue. In traditional chemical residue sampling, the cause of the heterogeneity may be spills or leaks that occur in several locations, or hot spots. In addition, concentrations vary depending on the distance from the source and on the different fate and transport mechanisms that work on the particular chemicals of concern (e.g., the degree to which particular chemicals adsorb to soil, are taken up in plants, or are taken up in solution during rain events). However, in general, the traditional chemical release is expected to follow a pattern of concentration flow from the release point based on known characteristics of the chemical and its common fate and transport mechanisms.

In the case of explosive material, substantial research conducted by CRREL has demonstrated that the manner in which explosive residues are distributed when released by an explosive force results in such a heterogeneous distribution of material that soil samples taken right next to each other can show vastly different concentrations. One sample may be a nondetect, while another a few feet away may show concentrations above action levels. Conducting a traditional risk assessment using discrete samples may cause the risk assessment to erroneously report no risk, simply because the munitions constituents were missed.

Recent studies illustrated that compositing samples provides more representative data for characterization of an area suspected of being contaminated with explosive compounds than analyzing discrete samples does.[125,126] The following paragraphs present the results of the studies.

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[125]T.F. Jenkins, M.E. Walsh. *Field-Based Analytical Methods for Explosive Compounds.* USA Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory.

[126]T.F. Jenkins, C.L. Grant, G.S. Brar, P.G. Thorne, P.W. Schumacher, and T.A. Raney. *Sampling Error Associated with Collection and Analysis of Soil Samples at TNT Contaminated Sites*, Field Analytical Chemistry and Technology 1: 151-163 (1997).

In both studies, seven discrete samples were collected with a hand corer in a wheel pattern (radius 61 cm) and field analyzed for TNT, HMX, and RDX. The results of the discrete sampling over a very short distance indicate a wide range of concentrations. Figure 8-3 shows the sampling scheme and the results of the discrete samples. The resulting comparison of the composite sample analysis as compared with the mean of the discrete sample results is shown on Figure 8-4. Each of the sampling points are two feet apart.

Figure 8-4 shows that the resulting standard deviation is much lower with composite sampling. All duplicate samples were sent to an independent commercial laboratory for analysis with acetonitrile extraction and RP-HPLC-UX as described in EPA Method 8330. The results of the laboratory analysis are also presented in Figure 8-4.

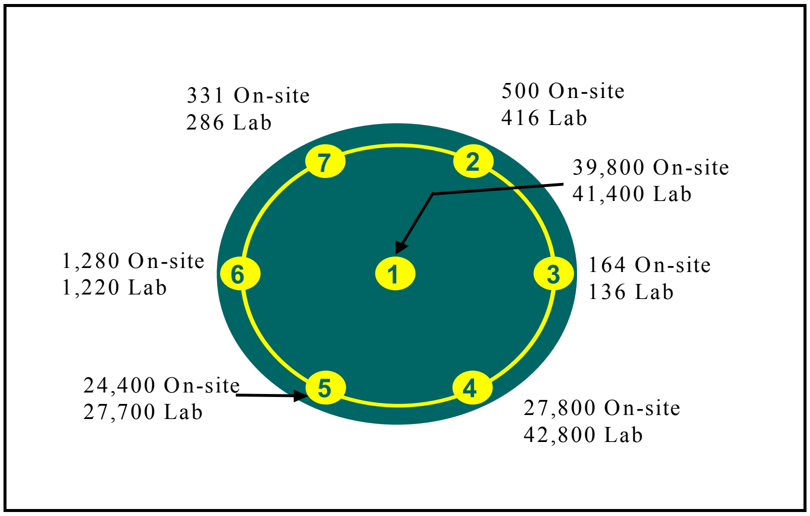

Figure 8-3. Sampling Scheme for Short-Range Heterogeneity Study: Monite Site, Sampling Location 1; Major Analyte: TNT (mg/kg)

			Discrete Samples			Composite Samples		
Sampling Location	**Major Analyte**	**Field or Lab**	**Mean**	**±**	**SD***	**Mean**	**±**	**SD**
Monite, location 1	TNT	F L	13,500 16,300	± ±	16,800 20,200	13,100 14,100	± ±	532 1,420
Monite, location 2	DNT	F L	16,100 34,800	± ±	11,700 42,200	23,800 33,600	± ±	3,140 2,390
Monite, location 3	TNT	F L	19.8 12.9	± ±	42.0 29.0	12.6 4.16	± ±	1.2 0.7
Hawthorne, location 4	TNT	F L	1,970 2,160	± ±	1,980 2,160	1,750 2,000	± ±	178 298
Hawthorne, location 5	TNT	F L	156 168	± ±	121 131	139 193	± ±	16.6 7.7
Hawthorne, location 6	Ammonium Picrate	F L	869 901	± ±	1,600 1,600	970 1,010	± ±	32 92

*The discrete sample standard deviations for locations 1, 2, 3, and 6 are larger than their corresponding means because the results from these locations are not distributed normally.

(Source: T.F. Jenkins, M.E. Walsh. *Field-Based Analytical Methods for Explosive Compounds.*)

Figure 8-4. Results of Composite and Discrete Samples: Soil Analyses: On-Site and Laboratory Methods, Monite Site and Hawthorne AAP (Source: Ibid.)

These findings reinforce the hypothesis that preparing a homogeneous and representative composite from a set of discrete samples is feasible and does not require sophisticated equipment nor exceptional time or effort. The use of composite samples also seems to effectively deal with the spatial heterogeneity associated with explosive residues.

In addition, the studies also indicate that distribution of explosive material within one field sample can vary so significantly that it can misrepresent the true concentration of explosive constituents in the area. To compound the matter even further, the traditional laboratory approach to soil sample preparation of a field sample usually involves taking a small amount of soil material from the top of the field sample container. This approach may miss explosive constituents altogether. For this reason, subsamples should be taken within a composite sample, with sample preparation consisting of mixing and grinding. CRREL studies have shown that mixing and grinding samples and subsamples can solve the problem.

There are many acceptable ways to collect and combine area-integrated samples into composite samples. The specific procedure chosen should be tailored to the conditions at the site to be characterized. By combining the ability to produce representative samples using on-site homogenization and compositing with the ability to obtain accurate analytical estimates with on-site methods, site investigators can minimize the problem of spatial heterogeneity for explosives-contaminated areas and the high costs normally associated with this sampling effort.

8.5.2 Selecting Analytical Methodologies

Two approaches may be used to determine the presence and concentration of munitions and munitions constituents in the environment. One approach is to conduct analysis in the field. This approach generates quantitative and qualitative data, depending on the exact method chosen, the compounds present, and their concentration range. The other approach is to collect samples in the field and analyze the samples in a laboratory. The laboratory can be either an on-site mobile laboratory or an off-site fixed laboratory. However, all shipments of materials with elevated concentrations of explosives must be conducted under Department of Transportation hazardous material transportation requirements.

The integrated use of both on-site field methods and laboratory methods provides a comprehensive tool for determining the horizontal and vertical extent of contamination, identifying potential detonation hazards, indicating the volume of contaminated media requiring remediation, and determining whether remediation activities have met the cleanup goals.

Field analysis provides nearly immediate results, usually in less than 2 hours, at lower costs than laboratory methods. It has been thought in general that field analysis is less accurate than laboratory methods (especially near the quantitation limit), that the methods have lower selectivity when the samples contain mixtures of munitions constituents, and that they are subject to more interferences. For these reasons, it was common practice that a set percentage of samples, between 10 and 20 percent of the total samples, was sent to a laboratory for additional analysis. In addition, fixed laboratory methods offer greater specificity, as most field methods respond to classes of munitions constituents.

However, recent studies described in the previous section may cause the reevaluation of this common practice. These studies demonstrate that the use of composite sampling, combined with on-site sample analysis and appropriate representative confirmation of results at an off-site environmental laboratory, (less than the typical 10 to 20 percent described above) can significantly reduce costs while maintaining accuracy.

8.5.3 Field Methods

Because of the heterogeneous distribution of explosive compounds in the environment, field analytical methods can be a cost-effective way to assess the nature and extent of contamination. The large number of samples that can be collected, combined with the relative speed with which data can be generated using field analysis, allows investigators to redirect the sampling during a sampling event.

Two basic types of on-site analytical methods are widely used for explosives in soil: colorimetric and immunoassay. Colorimetric methods generally detect broad classes of compounds, such as nitroaromatics, including TNT, or nitramines, such as RDX, while immunoassay methods are more compound-specific. Most on-site analytical methods have a detection range at or near 1 mg/kg for soil and 0.07 to 15 Fg/L for water.

Because TNT or RDX or both are usually present in explosives-contaminated soils, focusing on these two compounds during sampling can quickly identify areas of contamination. Studies of sampling and analysis at a number of explosives-contaminated sites reported “hits” of TNT or RDX in 72 percent of the contaminated soil samples collected and up to 94 percent of water samples collected that contained munition residues.[127,128] Another source reported that at least 95 percent of the soils contaminated with secondary explosive residues contained TNT and/or RDX.[129] Thus, the use of field methods for both of these compounds can be effective in characterizing explosives contamination at a site.

Field methods can be subject to positive matrix interferences from humic substances found in soils. For colorimetric methods, these interferences can be significant for samples containing less than 10 mg/kg of the target compound. In the presence of these interferences, many immunoassay methods can give sample results that are biased high compared to laboratory results. Commonly applied fertilizers, such as nitrates and nitrites, also interfere with many of these methods. Therefore, it is considered good practice to send a percentage of the samples collected to a fixed laboratory for confirmatory analysis.

Colorimetric methods treat a sample with an organic solvent, such as acetone, to extract the explosives. For example, for soil, a 2 to 20 gram sample is extracted with 6.5 to 100 mL of acetone. After 1 to 3 minutes, the acetone is removed and filtered. A strong base, such as potassium hydroxide, is added to the acetone, and the resulting solution’s absorbency at a specific light wavelength is measured using a spectrophotometer. The resulting intensity is compared with a control sample to obtain the concentration of the compound of interest.

Colorimetric methods, though designated for a specific compound, such as TNT or RDX, will respond to chemically similar compounds. For example, the TNT methods will respond to TNB, DNB, 2,4-DNT, and 2,6-DNT. The RDX methods will respond to HMX. Therefore, if the target compound, TNT or RDX, is the only compound present, the method will measure it. If multiple compounds are present, the concentration that you determine will be influenced by the presence of the interfering compound.

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[127] A.B. Crockett et al. *Field Sampling and Selecting On-Site Analytical Methods for Explosives in Soils*, U.S. Environmental Protection Agency, EPA/540/R-97/501, November 1996.

[128] A.B. Crockett et al. *Field Sampling and Selecting On-Site Analytical Methods for Explosives in Water*, U.S. Environmental Protection Agency, EPA/600/S-99/002, May 19, 1999.

[129] Thomas F. Jenkins et al. *Laboratory and Analytical Methods for Explosives Residues in Soil*, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.

The various immunoassay and biosensor methods differ considerably. However, the underlying basis can be illustrated by one of the simpler methods. Antibodies specific for TNT are linked to solid particles. The contaminated media are extracted and the TNT molecules in the extract are captured by the solid particles. A color-developing solution is added. The presence or absence of TNT is determined by comparing it to a color card or a field test meter.

Whereas colorimetric methods will respond to other chemically similar compounds, immunoassay methods are more specific to a particular compound. For example, the TNT immunoassay methods will also respond to a percentage of TNB, 2,4-DNT, and 2,6-DNT when multiple nitroaromatic compounds are present. The RDX immunoassay method has very little response (less than 3 percent) to other nitramines such as HMX.

The explosive compounds that can be detected by colorimetric and immunoassay methods are indicated in Table 8-3. In addition, TNT and RDX can be detected and measured in water samples using biosensor methods.

Examples of Field Analytical Methods

The EXPRAY Kit (Plexus Scientific) is the simplest colorimetric screening kit. It is useful for screening surfaces and unknown solids. It can also be used to provide qualitative tests for soil. It has a detection limit of about 20 nanograms. Each kit contains three spray cans:

EXPRAY 1 – Nitroaromatics (TNT)
EXPRAY 2 – Nitramines (RDX) and nitrate esters (NG)
EXPRAY 3 – Black powder, ANFO

EnSys Colorimetric Test Kits (EPA SW-846 Methods 8515 and 8510) consist of separate colorimetric methods for TNT and RDX/HMX. The TNT test will also respond to 2,4-DNT, tetryl, and TNB. The RDX/HMX test will also respond to NG, PETN, NC, and tetryl. It is also subject to interference from the nitrate ion unless an optional ion exchange step is used. The results of these kits in the field correlate well with SW-846 Method 8330.

DTECH Immunoassay Test Kits (EPA SW-846 Methods 4050 and 4051) are immunoassay methods for TNT and RDX. Immunoassay assay tests are more selective than colorimetric test kits. The results are presented as concentration ranges. These ranges correlate well with SW-846 Method 8330.

The EPA Environmental Technology Verification Program (http://www.epa.gov/etv) continues to test new methods.

Table 8-3. Explosive Compounds Detectable by Common Field Analytical Methods

Compound	Colorimetric Test	Immunoassay Test
Nitroaromatics		
2,4,6-Trinitrotoluene (TNT)	X	X
1,3-Dinitrobenzene (DNB)	X	
1,3,5-Trinitrobenzene (TNB)	X	X
2,4-Dinitrotoluene (2,4-DNT)	X	
2,6-Dinitrotoluene (2,6-DNT)	X	X
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	X	

Table 8-3. Explosive Compounds Detectable by Common Field Analytical Methods (continued)

Compound	Colorimetric Test	Immunoassay Test
Nitramines		
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	X	X
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	X	
Nitrocellulose	X	
Nitroglycerine	X	
Nitroguanidine	X	
PETN	X	

Figure 8-5 illustrates the results of regression analysis of the TNT results from the on-site colorimetric method compared with those of the laboratory HPLC method. The slope is very close to 1.0, which indicates that the on-site method provides essentially the same level of accuracy as the laboratory method. In addition, the correlation coefficient is high and the intercept value is low.

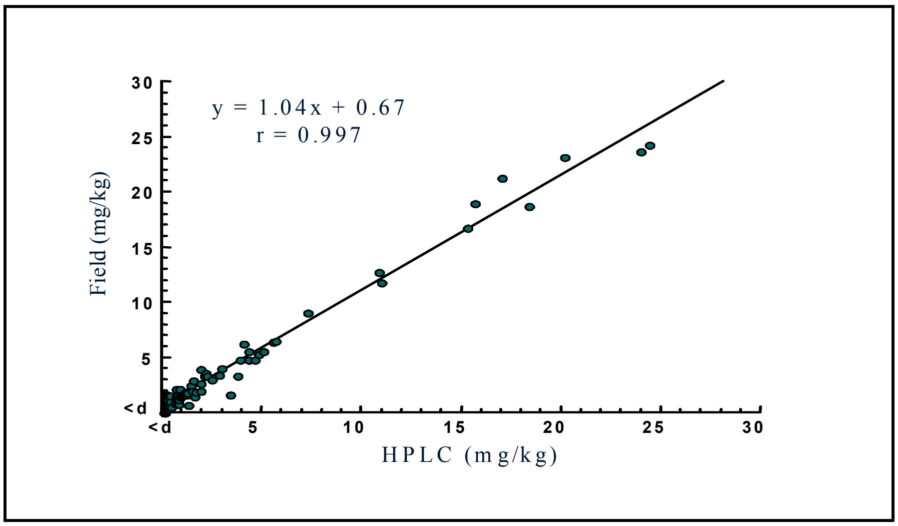

Figure 8-5. Comparison of Field and Fixed Laboratory Methods; Valcartier ATR: TNT Concentrations On-Site vs. Laboratory Results

8.5.4 Fixed Laboratory Methods

Explosive compounds such as TNT and RDX, as well as the impurities created during their manufacture and their environmental transformation compounds, are classified as semivolatile organic compounds (SVOCs). However, these compounds have a number of important chemical and physical properties that make their analysis by methods used for other SVOCs problematic. For example, if the concentration of energetic/explosive compounds is high enough (approaching 10 percent or less, depending on the specific compound), the possibility of detonation increases with the preparation of samples for analysis. Caution must be employed when using gas chromatography methods for the analysis of these compounds. Other problems exist when using gas chromatography due to the thermal lability and likelihood of degradation of certain compounds (e.g., HMX). These compounds are also very polar; thus, the use of the nonpolar solvents used in typical semivolatile analytical methods is not recommended.

8.5.4.1 *EPA Method 8330*

Samples containing or suspected of containing explosive compounds are usually analyzed using high-performance liquid chromatography (HPLC) with ultraviolet detection. If explosive compounds are detected, then the samples must be rerun using a second, different HPLC column for confirmation. The currently approved EPA method is SW-846 Method 8330, which provides for the detection of parts per billion (ppb) of explosive compounds in soil, water, and sediments.[130]

The compounds that can be detected and quantified by Method 8330 are listed in the text box to the right.

Samples can be extracted with methanol or acetonitrile for TNT, but acetonitrile is preferred for RDX. The sample extracts are injected into the HPLC and eluted with a methanol-water mixture. The estimatedquantitation limits in soil can range from 0.25 mg/kg to 2.2 mg/kg for each compound. The estimated quantitation limits in water can range from 0.02 to 0.84 Fg/L for low-level samples and 4.0 to 14.0 Fg/L for high-level samples. However, Method 8330 can give false positive results, especially at low concentrations. In such cases, the use of a liquid chromatography-mass spectrometry method, such as 8321, should be used for definitive confirmation. (See 8.5.4.3.)

Compounds That Can Be Detected and Quantified by SW-846 Method 8330 (EPA)

- 1,3-Dinitrobenzene (DNB)
- 1,3,5-Trinitrobenzene (TNB)
- 2-Amino-4,6-dinitrotoluene (2AmDNT)
- 2-Nitrotoluene
- 2,4-Dinitrotoluene (2,4-DNT)
- 2,4,6-Trinitrotoluene (TNT)
- 2,6-Dinitrotoluene (2,6-DNT)
- 3-Nitrotoluene
- 4-Amino-2,6-dinitrotoluene (4AmDNT)
- 4-Nitrotoluene
- Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)
- Methyl-2,4,6-trinitrophenylnitramine (Tetryl)
- Nitrobenzene
- Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)

8.5.4.2 *EPA Method 8095*

Method 8330, described above, is the standard EPA test method for explosive compounds. However, Method 8330 has a number of problems associated with it. These problems include high solvent usage, multiple compound coelutions (one or more compounds coming out at the same time) in sample matrices with complex mixtures, and long run times. In order to address these problems, EPA Method 8095 has been proposed as an alternative analytical method.[131] Method 8095 uses gas chromatography with electron capture detection (see text box). It can detect and quantify the same

[130] SW-846 Method 8330, Nitroaromatics and Nitramines by High Performance Liquid Chromatography (HPLC), U.S. Environmental Protection Agency, Revision 0, September 1994.

[131] Method 8095, Explosives by Gas Chromatography, U.S. Environmental Protection Agency, Revision 0, November 2000.

compounds as Method 8330. In addition, Method 8095 can also detect and quantify 3,5-dinitroaniline, nitroglycerine, and pentaerythritol tetranitrate (PETN).

Samples are extracted using either the solid-phase extraction techniques provided in Method 3535 (for aqueous samples) or the ultrasonic extraction techniques described in Method 8330 (for solid samples). Acetonitrile is the extraction solvent. Further concentration of the extract is only required for low detection limits. The extracts are injected into the inlet port of a gas chromatography equipped with an electron capture detector. Each analyte is resolved on a short, wide-bore, fused-silica capillary column coated with polydimethylsiloxane. Positive peaks must be confirmed on a different chromatography column. The major disadvantage of this method is the lack of commercial availability.

8.5.4.3 *Other Laboratory Methods for Explosive Compounds*

Two other methods can be mentioned briefly. The first is a CHPPM method for explosives in water. It is a gas chromatography electron capture detection method developed by Hable and others in 1991. Although it is considered to be an excellent method, it is not commercially available. The second, SW-846 Method 8321, is an LC-MS method that is available at a few commercial laboratories. Explosives are not the target analytes for which the method was developed; however, the method claims to be applicable to the analysis of other nonvolatile or semivolatile compounds.

8.5.4.4 *EPA Method 7580*

In addition to explosive compounds, other materials used in military ordnance present hazards to human health and the environment. White phosphorus (P_4) is a toxic, synthetic substance that has been used in smoke-producing munitions since World War I. Due to the instability of P_4 in the presence of oxygen, it was originally not considered an environmental contaminant. However, after a catastrophic die-off of waterfowl at a U.S. military facility was traced to the presence of P_4 in salt marsh sediments, it was discovered that P_4 can persist in anoxic sedimentary environments.

Method 7580, gas chromatography with nitrogen/phosphorus detector, may be used for the analysis of P_4 in soil, sediment, and water samples.[132] Two different extraction methods may be used for water samples. The first procedure provides a detection limit on the order of 0.01 Fg/L. It may be used to assess compliance with Federal water quality criteria. The second procedure provides fora detection limit of 0.1 Fg/L. The extraction method for solids provides a sensitivity of 1.0 Fg/kg. Because this method uses the nitrogen/phosphorus detector, no interferences have been reported.

Because P_4 reacts with oxygen, sample preparation must be done in an oxygen-free environment, such as a glove box. Samples are extracted with either diethyl ether (low water method), isooctane (high water method), or degassed reagent water/isooctane (solids). The extracts are then injected into the gas chromatograph that has been calibrated with five standards.

8.5.4.5 *Perchlorate Analytical Methods*

One munitions constituent that has appeared on the scene in recent years is the perchlorate anion. Ammonium perchlorate is a major component of solid rocket fuel. Perchlorate compounds are also used in a variety of other items, including mines, torpedo warheads, smoke-generating

[132]Method 7580, White Phosphorus (P_4) by Solvent Extraction and Gas Chromatography, U.S. Environmental Protection Agency, Revision 0, December 1996.

compounds, signal flares, parachute flares, star rounds for Very pistols, spotting charges for training rounds, thermite-type incendiaries, small arms tracers, fireworks, and airbags. As a result of various activities with these assorted items, including manufacturing, storage, weapons training, washout, burning, burial, and detonations, perchlorate contamination has become very widespread. It is believed to have migrated into the groundwater of at least 30 States. Most of the reported contamination in the United States ranges from 4 to 100 Fg/L.

The most controversial aspect of perchlorate contamination is the level at which perchlorate poses a human health risk. Some States have advocated a drinking water standard for perchlorate in the low parts per billion range. Though EPA currently does not officially regulate perchlorate, it is requiring monitoring for it under the Safe Drinking Water Act's Unregulated Contaminant Monitoring Rule (UCMR). Perchlorate in waste water may also be monitored under a National Pollutant Discharge Elimination System (NPDES) permit. Several States, including California, are issuing interim action levels that are close to the low end of the range.

The only analysis method for perchlorate approved by EPA is Method 314.0. This method was developed for use with drinking water and is required by the UCMR. Its use may also be required in individual NPDES permits. Method 314.0 uses ion chromatography with conductivity detection. The detector is nonspecific, that is, it does not measure perchlorate specifically. It only measures the change in the conductivity of the water eluting from the chromatography column. The identification of perchlorate is made based on the retention time for the ion in the chromatography column. Though the method requires calibration, the presence of unknown interferences and shifts in retention time caused by high total dissolved solids can result in erroneous data (false positives or false negatives), particularly at the low end of detection (about 4 Fg/L). These sources of interference are more common in non-drinking-water samples (e.g., groundwater or wastewater). DoD policy currently requires confirmation of positive detections made by Method 314.0 such as those using mass spectrometry.

Several methods for perchlorate analysis are under development. An improved method 314 that uses additional cleanup and a second confirmatory column is expected to be promulgated by the EPA Office of Water soon, as are methods that make use of mass spectrometry (MS) or MS/MS detectors and ion-pair ratio monitoring, with or without O^{18} spiking. Work has also been done on a method that uses an ion-specific electrode. The use of these newer methods as they come online will result in a higher level of confidence in the analytical data. In addition to the definitive methods described above, a number of field methods are in the process of development and testing.[133]

8.6 Developing the Site Response Strategy

Most of this chapter has focused on the essential components of the systematic planning process that will be used to devise the sampling and analysis strategy appropriate for your site. The question remains – what do you do with this information?

The information from your site investigation will be documented in an investigation report (called a remedial investigation report in the CERCLA program and a RCRA facility investigation report in the RCRA program). In the standard CERCLA process addressing chemical contamination, this information will be evaluated with a site-specific risk assessment to determine whether the

[133] P.G. Thorn. *Field Screening Method for Perchlorate in Water and Soil*. Cold Regions Research and Engineering Laboratory. ERDC/CRREL TR-04-8. April 2004

concentrations of chemicals present at the site provide a potential risk to human health and the environment and whether pathways between chemicals present at the site and potential receptors will expose receptors to unacceptable levels of risk. When evaluating the munition constituents of MEC, the standard risk assessment process will be used.[134]

When evaluating the information associated with an MRS (UXO, explosive soil, and buried munitions), two questions are asked:

- Is any MEC present or potentially present that could pose a risk to human health or the environment?
- What is the appropriate **site response strategy** if MEC is present or potentially present? Three fundamental choices are evaluated:
  - Further investigation is required.
  - Response action is required (either an active response such as clearance or containment, or a limited response such as institutional controls and monitoring).
  - No action or no further action is required.

8.6.1 Assumptions of the Site Response Strategy

The site response strategy is based on several basic assumptions built on discussions with DoD MEC experts:

> **What Does "Unacceptable Risk" Mean**
>
> If there is no acceptable risk level, does that mean 100 percent cleanup at all sites?
>
> The short answer is no. Institutional controls (ICs) will be used along with the active response when that response allows a land use that does not provide for unrestricted use. ICs may be used as the sole response in those circumstances where the CERCLA decision process finds that active response actions are impracticable or unsafe.

- There is no quantifiable risk level for MEC exposure below which you can definitively state that such potential exposure is acceptable. This is because exposure to only one MEC item can result in instantaneous physical trauma. In other words, if the MEC item has a potential for exposure, and a receptor comes into contact with it and the MEC item explodes, the result will be death or injury. Unlike noncarcinogenic chemicals, MEC does not have an acceptable risk level that can be quantified, above which level there is a risk that injury will occur. Unlike carcinogenic chemicals, there is no risk range that is considered to be acceptable. Explosive risk either is or is not present. It is not possible to establish a threshold below which there would be no risk, other than the absence of MEC. Therefore, no attempt is made to quantify the level of explosive risks.
- Once MEC is determined to be present or potentially present, a response action will

[134]U.S. EPA. *Risk Assessment Guidance for Superfund* (RAGS), Volume 1, *Human Health Evaluation Manual*, Part B, Interim, September 1991.

be necessary. This response action may involve removal, treatment, or containment of MEC, or it may be a limited action such as the use of institutional controls and monitoring. In any case, whenever the response action will leave MEC present or potentially present on-site after the action is complete, some kind of institutional controls will be required.[135]

EPA/DoD Interim Final Management Principles on Land Use and Clearance

- Because of technical impracticability, inordinately high costs, and other reasons, complete clearance of MRSs may not be possible to the degree that allows certain uses, especially unrestricted use. In almost all cases, land use controls will be necessary to ensure protection of human health and public safety.
- Land use controls must be clearly defined and set forth in a decision document.
- Final land use controls for a given MRS will be considered as part of the development and evaluation of response alternatives using the nine criteria established under CERCLA regulations (i.e., the National Contingency Plan, or NCP) or equivalent RCRA process. The decision will be supported by a site characterization adequate to evaluate the feasibility of reasonably anticipated future land uses. This will ensure that land use controls are chosen based on a detailed analysis of response alternatives and are not presumptively selected.

- A no-action alternative (i.e., not even institutional controls are required) will usually be selected only where there is a high level of certainty that no MEC is present on-site. The selection of "further investigation" will usually occur when the site information is qualitatively assessed and deemed sufficiently uncertain that proceeding to some sort of response action (or no action) is inappropriate.
- The final decision at the site (no action, or selection of a type of action) is formally evaluated through whatever regulatory process is appropriate for the site. For example, if your decision is to be made under the CERCLA remedial process, you would use the nine CERCLA criteria to evaluate the acceptability of a no-action decision and to select appropriate response actions (including depth of response or containment, or limited response actions such as institutional controls and monitoring).

8.6.2 Attributes of the Site Response Strategy

It will not be necessary to create a new report to document your site response strategy. The site response strategy is not a new document or a new process. Rather, it is the pulling together of the information from your investigation to set the stage for the next steps in the MEC management process at your site. The site response strategy can be developed whenever there is enough information available to make the decision you were initially trying to make (or to determine that additional information is necessary). The site response strategy can be documented through a number of existing documents, including:

[135]Institutional controls are nonengineered measures designed to limit exposure to hazardous substances, pollutants, or contaminants that have been left in place and that are above levels that support unrestricted use. They are sometimes referred to by the broader term "land use controls." The latter term encompasses engineered access controls such as fences, as well as the institutional or administrative mechanisms required to maintain the fence.

- The work plan for the next stage of work (if more investigation is necessary).
- The conclusion section of the RI or RFI (if no action is recommended).
- The feasibility study (if a response action is planned).

Key attributes of the site response strategy include the following:

1. **It uses a weight-of-evidence approach to decision making.** Converging lines of evidence are weighed qualitatively to determine the level and significance of uncertainty. In the process of developing a site response strategy, information is gathered from a variety of sources – historical data, facility and community interviews, surface inspections, geophysical inspections, and land use and planning information. Decisions are based on a qualitative analysis of the data collected. The gathering of this information takes place during the site characterization phase.

2. **The site response strategy may be determined using varying levels of data at different points in the data collection process and is thoroughly integrated with the site characterization process.** It is not a separate step. The project team is asked to examine the weight of evidence present, and the amount of uncertainty present, at any stage in your data collection process to determine the next course of action (e.g., more investigation, response, institutional controls only, or no action). Three examples are used to illustrate this point:

    — If historical information from multiple sources over continuous timeframes provides sufficient certainty that no MEC is present, then it may not be necessary to conduct geophysical studies to detect MEC and determine the depth and boundaries of the MEC.

    — If there is uncertainty as to whether ordnance with explosive potential is present, or is present at depths that could lead to exposure, then extensive geophysical investigations may be required to determine the presence or absence of MEC and the depth at which it may be found.

    — If ordnance with explosive potential is known to be present at a depth where human exposure is likely, then it may not be necessary to conduct extensive geophysical studies to determine if factors are present that would cause MEC items to migrate.

3. **The purpose of the site response strategy is to enable the project team to make a risk management decision (the remedy selection process).** The site response strategy considers information gathered in the site characterization phase that validates and/or changes the conceptual site model. The type and location of MEC, the availability of pathways to potential receptors, the accessibility of the site(s) to receptors, and the current, future, and surrounding land uses are assessed to determine the type and magnitude of risks that are associated with the site(s). The site response strategy informs the risk management process, which compares the risks associated with clearance with those of exposure management (through physical or institutional controls). The strategy then uses the appropriate regulatory processes (e.g., CERCLA, RCRA, SDWA, etc.) to determine the final remedy at the site.

Figure 8-6 provides an overview of the process of developing a site response strategy. It shows the various types of investigations, uncertainties, and decisions that go into the development of a site response strategy. The figure illustrates typical investigation and decision scenarios. The reader should note that there are no endpoints on this flow chart, since the stage that follows the site response strategy is either further investigation or evaluation of potential remedies. The discussion that follows outlines in more detail the series of questions and issues to be weighed at each decision point.

8.6.3 Questions Addressed in the Development of the Site Response Strategy

In developing your site response strategy, you will address four issues. These four issues parallel the factors addressed in a typical risk assessment, but the process differs significantly from a risk assessment in that after the initial question (presence or absence of ordnance) is addressed, the focus of the remaining questions is to develop a response strategy to support the risk management approach.

8.6.3.1 *Determining the Presence of Munitions with Explosive Potential*

The central question addressed here is whether munitions with explosive potential is present or may be present at your site. As discussed earlier, the response to this question is a simple yes or no answer. A former firing range in which the only type of munition used was bullets will probably be found to have no explosive risk. (There may of course be risks to human health and the environment from munitions constituents such as lead, but such risks are addressed in a chemical risk assessment.) Larger munitions items (e.g., bombs, projectiles, or fuzes) will have an explosive risk if present or potentially present as MEC.

Establishing the Presence or Absence of MEC Using Historical Data

- Mission of the facility and/or range
- Actual use of facility and/or range over time
- Types of ordnance associated with the mission and actual use
- Accessibility of the facility and ranges to human activity that could have resulted in unplanned burial of excessed ordnance or souvenir collecting
- Portability of UXO (facilitating unplanned migration to different parts of the facility)

Sources of Information

- Archive reports
- EO incident reports
- Interviews with base personnel and surrounding community
- Aerial photographs
- Newspaper reports

As discussed in Chapters 3 and 4 and in preceding sections of this chapter, in your investigation to determine the presence or potential presence of MEC you would consider multiple sources of information, including historical information (see text box above) and a variety of geophysical studies. An initial gathering of historical information will be necessary to create the conceptual site model that will guide both intrusive and nonintrusive studies of the site. Visual reconnaissance may also be appropriate to identify evidence of range activity and to highlight areas for further investigation. Finally, various types of geophysical studies may be used to locate potential MEC.

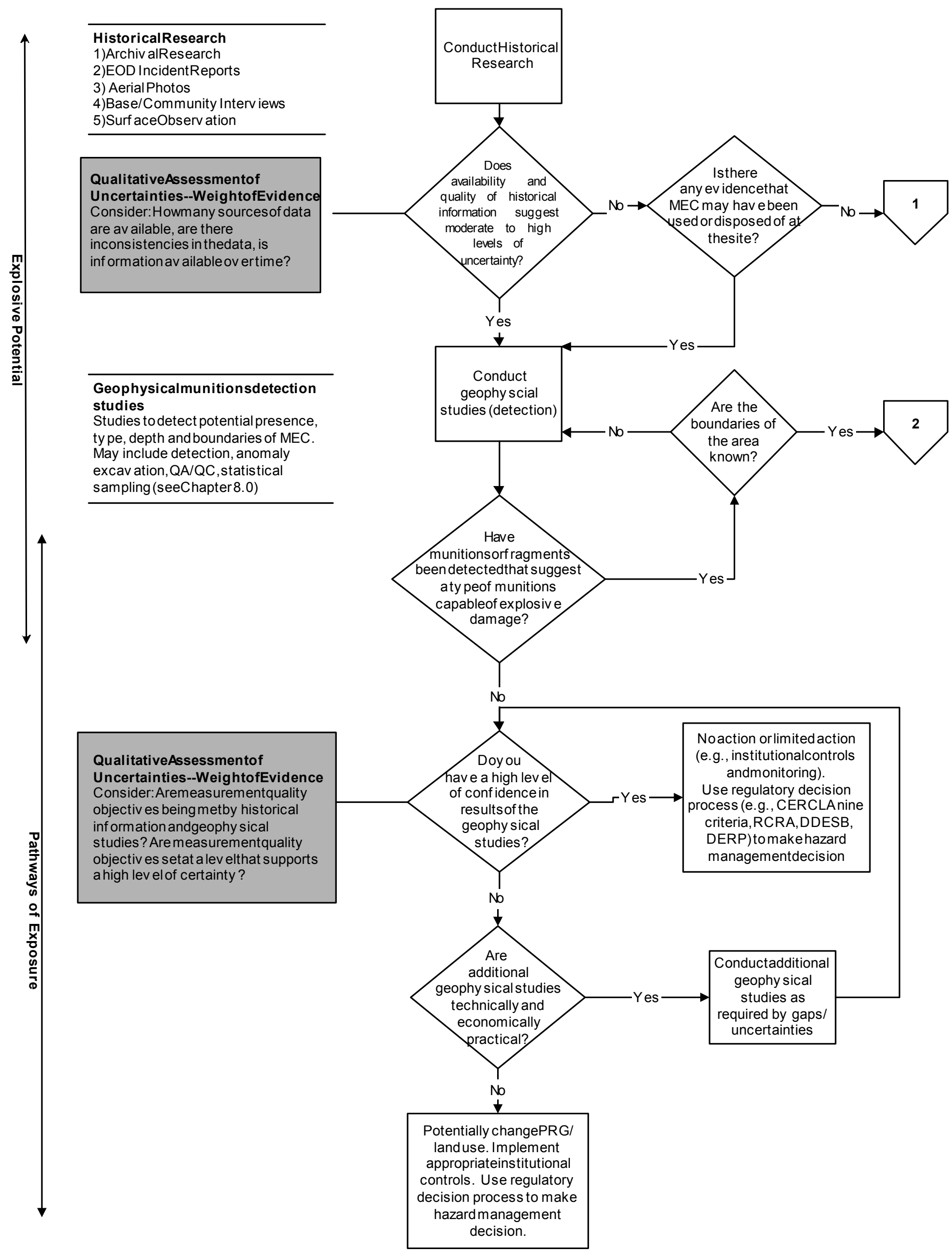

Figure 8-6. Developing a Site Response Strategy

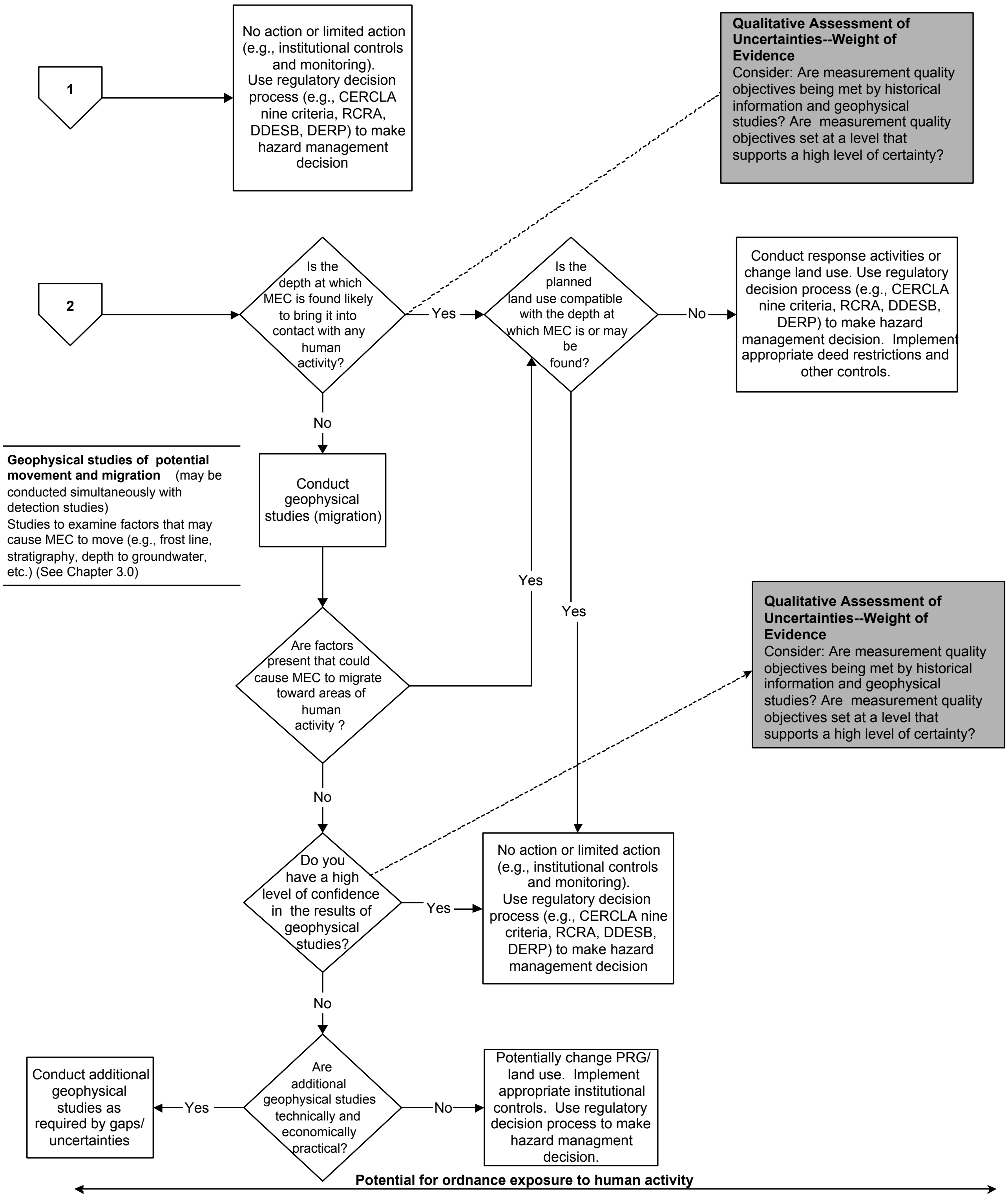

Figure 8-6. Developing a Site Response Strategy (continued)

8.6.3.2 *Identifying Potential Pathways of Exposure*

Once the actual or potential presence of MEC has been established, you will then need to identify the potential exposure routes. The essential question in this phase is whether the ordnance that is found in the area is, or could be, at a depth that will bring it into contact with human activity. In the site characterization, you established the preliminary remediation goal (PRG), which specifies the depth to which clearance will be required to support the anticipated land use. Using historical information and geophysical data, you should consider two questions:

- Has ordnance, fragments of ordnance, or explosives-contaminated soil been detected, suggesting the presence of MEC? (Is there munitions with explosive potential?)
- Is this material found at a depth that is shallower than the PRG (and likely to bring it into contact with human activity)?

If the ordnance is not found at a depth that is shallower than the PRG, additional geophysical studies may be necessary to determine if there are factors that may cause ordnance to move (e.g., frost line or stratigraphy). (See Chapter 3 and earlier in this chapter.)

> **Factors To Be Evaluated in Identifying Potential Pathways of Exposure**
>
> In addition to the information highlighted in the previous box (regarding the historical uses of, and likely ordnance at, the site), factors that affect pathways of exposure include:
>
> - Current and future land use, and depth to which land must be clear of MEC to support that land use; level of intrusive activity expected now and in the future
> - Maximum depths at which ordnance is or may be found, considering the nature of the ordnance
> - Location of frost line
> - Erosion potential
> - Portability of type of ordnance for souvenir handling and illegal burial
> - Potential that excessed ordnance may have been buried

If ordnance is found to be present or potentially present, you may need additional geophysical information in order to ensure that the boundaries of the range and the density of ordnance are well understood for the purposes of assessing the complexity (and cost) of remediation.

> **About Portability**
>
> The potential of exposure to MEC through human activity goes beyond the actual uses of ranges. Potential exposures to MEC can also occur as a result of human activity that causes MEC to migrate to different locations. Examples of such common human activities include:
>
> - Burial of chemical protective kits (containing chemical waste material) by soldiers in training exercises.
> - Transport of UXO as souvenirs to residential areas of the base and off base by soldiers or civilians.

8.6.3.3 *Determining Potential for Human Exposure to MEC*

The potential for human exposure is assessed by looking at the types of human activities that might bring people into contact with MEC. Key issues for determining the potential of human receptors to come into contact with MEC include:

- Depth of ordnance MEC and exposure pathways of concern
- Potential for naturally caused migration to depths of concern

- Accessibility of areas where MEC is known or suspected to be present to workers, trespassers, etc.
- Potential for intrusive activity (e.g., construction in the MRS)
- Current and potential future ownership of the site(s)
- Current and potential future land use of the site(s) and the surrounding areas (including potential groundwater use)
- Potential portability of the MEC (for potential human-caused migration off range)

During the final phase of the analysis, you should consider information and uncertainties from all phases of the investigation to determine whether there is a risk at the depth of concern. If the planned land use is not compatible with the depth at which ordnance is or may be found, then two options are possible:

- Remediate to a depth appropriate for the planned land use.
- Change the planned future land use to be consistent with the depth of cleanup.

Both of these decisions will be made during the risk management decision process under the applicable regulatory framework (e.g., CERCLA or RCRA). Unless you have a high level of certainty that remediation will clear the land for an unrestricted land use, appropriate institutional controls will be required.

8.6.3.4 *Considering Uncertainty*

In every stage of site characterization, including the development of a site response strategy, a qualitative evaluation of uncertainty will help you decide the level of confidence you have in the information collected to determine your next steps. No single source is likely to provide the information required to assess the level of certainty or uncertainty associated with your analysis. Therefore, your qualitative uncertainty analysis will rely on *the weight of the evidence that has converged* from a number of different sources of data, including historical information (archives, EOD incident reports, interviews, etc.), results of detection studies and sampling, results of other geophysical studies, assessment of current and future land use, and accessibility of MRAs/MRSs.

8.7 Framework for Making the Decision

The Interim Final Management Principles agreed to by senior DoD and EPA managers (described in and provided as an attachment to Chapter 2, "Regulatory Overview") establish a framework for making risk management decisions. These principles state that "a process consistent with CERCLA and these management principles will be the preferred response mechanism used to address UXO at a range." The principles go on to state that response actions may include CERCLA removal or remedial activities, or some combination of these, in conducting the investigation and cleanup.

8.8 Conclusion

The focus of this chapter has been on planning your investigation. In the course of the investigation, the initial plan will undoubtedly change. The conclusion of the investigation should result in answers to the questions posed in the data quality objectives at a level of certainty that is acceptable to the DoD decision makers, the regulators, and the public.

The purpose of this chapter has been to take you through the design of the MEC investigation to the development of a site response strategy. As pointed out in the introduction, this chapter has focused primarily on MEC and energetic materials, not the environmental contamination of media by munition constituents. Chapter 3 describes common chemicals of concern that are found in association with MRAs. Typically, the approaches used to investigate explosive compounds will not differ substantially from other environmental investigations of hazardous wastes, pollutants, and contaminants, except that safety considerations will require more extensive health and safety plans and generally be more costly since the potential for MEC in the subsurface must be considered.

The development of a site response strategy is based on the Interim Final Management Principles, which call for investigation and cleanup actions to be consistent with both the CERCLA process (either removal or remedial activities, or a combination of these) and the principles themselves. The actual selection of a response will be conducted through the risk management processes defined by the CERCLA removal and remedial programs (or the RCRA Corrective Action Program).

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

Crockett, A.B., H.D. Craig, T.F. Jenkins, and W.E. Sisk. ***Field Sampling and Selecting On-site Analytical Methods for Explosives in Soil***. U.S. EPA, Federal Facilities Forum, Dec. 1996; EPA/540/S-97/501. Available at URL: http://www.epa.gov/nerlesd1/tsc/images/fld-smpl.pdf.

Crockett, A.B., H.D. Craig, and T.F. Jenkins. ***Field Sampling and Selecting On-site Analytical Methods for Explosives in Water***. U.S. EPA, Federal Facilities Forum, May 19, 1999; EPA/600/S-99/002.Available at URL: http://www.epa.gov/nerlesd1/tsc/images/water.pdf.

U.S. Army. ***Military Explosives***. Department of the Army Technical Manual. TM 9-1300-214. September 1984.

Wilcox, R.G. ***Institutional Controls for Ordnance Response***. Paper presented at UXO Forum 1997, May 1997.

Information Sources

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http://www.ddesb.pentagon.mil

U.S. Environmental Protection Agency
Superfund Risk Assessment
http://www.epa.gov/superfund/programs/risk/index.htm

<u>**Guidance Documents**</u>

U.S. Air Force, Headquarters, Air Force Center for Environmental Excellence. ***Technical Services Quality Assurance Program***. Version 1.0, Aug. 1996.

U.S. Army Corps of Engineers. ***Requirements for the Preparation of Sampling and Analysis Plans***. Manual EM 200-1-3. February 1, 2001.

U.S. Army Corps of Engineers. ***Chemical Data Quality Management for Hazardous, Toxic, Radioactive Waste Remedial Activities***. ER 1110-1-263. April 30, 1998.

U.S. EPA. ***Guidance on Conducting Non-time-critical Removal Actions Under CERCLA***. NTIS No. PB93-963402; Aug. 1993.

U.S. EPA. ***Guidance for Data Usability in Risk Assessment (Part A)***. NTIS No. PB92-963356; Apr. 1992.

U.S. EPA. ***Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents***. NTIS No. PB98-963241; July 1999.

U.S. EPA. ***Institutional Controls and Transfer of Real Property Under CERCLA Section 120(h)(3)(A), (B) or (C)***. Feb. 2000.

U.S. EPA. ***Risk Assessment Guidance for Superfund (RAGS), Volume I – Human Health Evaluation Manual, Part A***. Interim Final. Dec. 1989.

U.S. EPA. ***Risk Assessment Guidance for Superfund (RAGS), Volume I – Human Health Evaluation Manual, Part C (Risk Evaluation of Remedial Alternatives)***. Interim Final. Oct. 1991.

U.S. EPA. ***Risk Assessment Guidance for Superfund (RAGS), Volume I – Human Health Evaluation Manual, Part B***. Interim Final. Dec. 1991.

U.S. EPA. ***Risk Assessment Guidance for Superfund (RAGS), Volume I – Human Health Evaluation Manual, Part D (Standardized Planning, Reporting, and Review of Superfund Risk Assessments)***. Interim Final. Jan. 1998.

U.S. Navy. ***Environmental Compliance Sampling and Field Testing Procedures Manual***. NAVSEA T0300-AZ-PRO-0010; July 1997.

9.0 UNDERWATER MUNITIONS AND EXPLOSIVES OF CONCERN

Throughout this handbook, we have discussed a wide range of technical issues associated with MEC when it is found on land. All of the problems, issues, and concerns can be multiplied several times when MEC is found underwater. As with land-based MEC, the concerns involve risks to human health, the environment, and explosive hazards. However, the routes of exposure and the fate and transport for land-based and underwater ordnance can be different. There are a number of uncertainties that affect our decision-making regarding the management of MEC in the underwater environment. These include, but are not limited to, the following:

> **Snagging WWII Underwater Munitions**
>
> In July 1965, a fishing trawler off the coast of North Carolina snagged a World War II German torpedo in its nets. As the crew attempted to lift the torpedo clear of the water in heavy seas, the warhead hit the side of the trawler and detonated. Eight of the twelve crewmen died and the vessel sank.
>
> Source: A. Pedersen, *The Challenges of UXO in the Marine Environment,* Naval EOD Technology Division. Modified by written communication.

- Information on the fate and transport of munitions constituents in the underwater environment is lacking or not widely distributed.
- Finding underwater MEC offers additional complexities in detection, discrimination, and positioning.
- Safety issues can be magnified in the underwater environment.
- For reasons of personal safety, blowing in place (BIP) is (as it is on land) the common method for disposing of UXO unless the UXO item has been determined to be safe to move. (However, if conducting underwater BIP, the effects of underwater detonation to humans and the underwater ecosystem must be addressed.)

This chapter addresses what is known about the areas listed above, as well as the uncertainty in each area. The chapter is divided into four parts.

- Design of a conceptual site model for underwater ranges
- Detection of underwater MEC
- Safety
- Underwater response technologies

9.1 Conceptual Site Model for Underwater Environments

This section addresses the unique factors in designing a conceptual site model (CSM) for underwater MEC, including the following:

- The areas where underwater MEC is found,
- The potential for exposure to MEC,
- The environmental factors affecting decomposition of underwater MEC, resulting in potential for releases of munition constituents,
- The environmental fate and transport of munitions constituents, and
- The ecological and human health effects and toxicity of explosive compounds and other munitions constituents in the underwater environment.

9.1.1 Areas Where Underwater MEC Is Found

Much of the U.S. underwater MEC presence has occurred near military practice and test ranges. Activities at locations such as ammunition piers, coastal bombing ranges, and dredge spoil ponds, among others, have also resulted in a wide variety of MEC items. In addition, war, intentional dumping, and accidental dumping have contributed to the problem.

Some of the military activities that have historically resulted in underwater MEC contamination are described below:

- **Ammunition storage and transfer activities** – MEC may be deliberately or accidentally dumped near piers where ships load and unload munitions or materiel (mishandling/loss).
- **Weapons training and testing** – For some kinds of training, the underwater environment, particularly the deep ocean, may be target impact areas and areas where underwater munitions such as sea mines or torpedoes were used. These areas include ships that are used as practice targets. Other weapons training activities may have a range safety fan that includes a body of water where munitions that miss the target might land. MEC can include dud-fired munitions, low-order detonations, intact munitions, and dumped munitions (mishandling/loss).
- **Troop training areas** – Training areas may be on shorelines (near wetlands, ocean beaches, tidal wetland areas, etc.) or over rivers, lakes, or ponds. As in land-based training, unauthorized disposal, or loss of material, can result in MEC in underwater areas. Overshoots and undershoots on islands used as targets for aerial bombing, missiles, and naval artillery can also result in MEC in underwater areas. Examples of where such events have occurred include Nomans Land Island, Massachusetts, Kaho'olawe Island, Hawaii, and Adak, Alaska.
- **Disposal of MEC** – In the past, large- or small-scale dumping of military munitions occurred offshore.[135] In addition, disposal of underwater UXO may result in chunks of MEC released from low-order detonations. These disposal operations could have resulted in the introduction of munitions constituents to the aquatic environment.

9.1.2 Potential for Exposure to MEC

Potential human exposures to underwater MEC or UXO result from different factors than land-based exposures. Both land-based and underwater exposure can be from recreational and industrial uses, but other potential exposures are unique to the underwater environment (see Figure 9-1). Table 9-1 shows examples of activities and potential exposure. In addition, underwater MEC can migrate as a result of tides, surf, currents, floods, or other factors.

[135] As used in this handbook, the term *offshore* refers to the area that is in the intertidal area and further out.

Table 9-1. Exposure Scenarios from Underwater MEC and UXO

Potential Receptor Activity	Exposure Pathway	MEC Hazard and Risk Type
Near-shore recreational use, (e.g., swimming, fishing)	Beaches, shorelines, river bottoms, sediments	Explosive hazard, munitions residue
Port and channel maintenance such as dredging and dredge spoil disposal	River bottoms, sediments	Explosive hazard, munitions residue
Commercial fishing, trawling for fish	Fishing activity that brings up unknown items	Explosive hazard
Deep sea recreational use such as diving	Coral reefs, other underwater formations, sunken ships	Explosive hazard
Consumption of seafood	Food chain	Munitions residue
Fish feeding areas, nurseries	Sediments, benthic organisms	Munitions residue

In addition to the potential receptor activities and related exposure pathways listed in the table, the disposal of ordnance in the underwater environment is another exposure pathway that may be difficult to control. As discussed in Chapter 5, blow-in-place is usually the preferred method for disposing of UXO because of safety considerations. This is true in underwater environments as well as on land. However, the underwater detonation of UXO may pose a significant risk to underwater ecological receptors and sensitive habitats, including wetlands, estuaries, coastal areas, and marine habitats such as coral reefs.

In the example presented below, one naval facility began the design of its conceptual site model by dividing the offshore area into four offshore clearance zones. These zones were based on likely human access due to water depth, with the flexibility to change a zone as appropriate. These offshore clearance zones were defined as follows:[136]

- Zone 1: The portion of the sea floor that is not covered by water most of the time and can be walked on during low tides — Intertidal zone
- Zone 2: The portion of the sea floor that is easily accessible by wading from the shore but is covered by water most of the time — Shallow subtidal zone
- Zone 3: The portion of the sea floor that is not accessible by wading but is accessible by skin diving from a boat or a pier — Intermediate subtidal zone
- Zone 4: The portion of the sea floor that is accessible only by self-contained underwater breathing apparatus (SCUBA) or surface-supplied-air diving — Deep subtidal zone

The offshore clearance zones and zone depths are shown in cross-section in Figure 9-1.

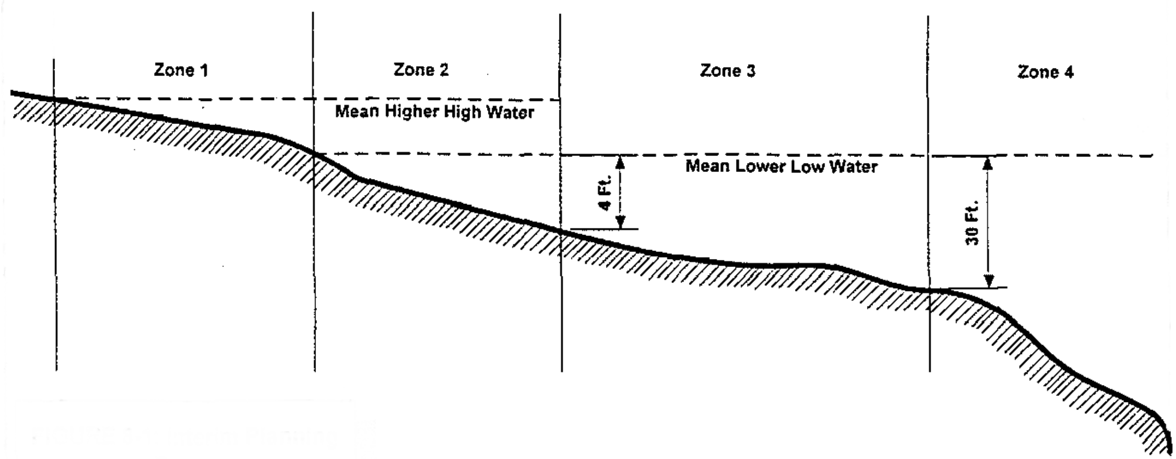

Figure 9-1. Example of Offshore Clearance Zones

9.1.3 Environmental Factors Affecting Decomposition of Underwater MEC Resulting in Releases of Munitions Constituents

A number of complex factors affect the fate and transport of munitions constituents released in the underwater environment. These factors include the nature of the delivery of the munition item to the underwater environment, its potential for corrosion, and associated releases.

Underwater releases of munition constituents can occur when casings deteriorate, (most notably from corrosion), rupture upon impact, or undergo a low-order detonation. Munitions

[136]Technical Memorandum for Offshore OE Clearance Model, OE Investigation and Response Actions, Former Mare Island Naval Shipyard (MINS). Prepared for Commander, Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. February 11, 1999.

constituents may be released immediately after impact or may be only partially contained within the remains of the delivery system. When UXO undergoes a low-order detonation or breaks apart upon impact, the munitions constituents, such as bulk explosives, can be scattered over the impact area.[137] (See Section 3.2.3). When the MEC remains relatively intact, munitions constituents can be released through pinhole cracks that develop over time as a result of corrosion or through the screw threads linking the fuze assembly to the main charge.

Corrosion of the iron and steel in MEC casings is a complex process that occurs in the presence of water and oxygen. The potential corrosivity of the local environment, such as a bay, harbor, lake, pond, or wetland, could vary greatly. Such variations can be caused by acid rain, industrial pollution, salinity, degree of oxygen saturation, or natural buffering caused by the presence of carbonate rocks or other minerals. Normally, the lower the pH of the environment, the higher its corrosive potential.

The effects of immersion and corrosion on the release of munition constituents in various underwater environments depend on site conditions. Even though saltwater is potentially more corrosive the higher the salt saturation, exposure to oxygen is a key requirement for corrosive effects. In environments where wave action and tides cause mixing with the atmosphere, the oxygen content of the water, especially shallow water, can be at or near the saturation point, creating a high potential for oxidation. Likewise, repeated exposure of MEC items directly to the oxygen in the atmosphere through tidal movement can increase corrosion.

Recent studies have suggested that even corroded MEC does not necessarily result in the harmful release of munition constituents. A variety of factors in the underwater environment may either reduce the potential for corrosion, or affect the nature of the release from an MEC item releasing munition constituents. At higher pH levels, if the right conditions are present (e.g., CO_2 saturation, or temperature) submerged or buried metal may develop a coating of calcium carbonate, with a corresponding increase in corrosion resistance. In the absence of oxygen, such as the anaerobic conditions that can exist where there are large concentrations of unoxidized metals, or high content of organic matter, or in deeper, cold waters, corrosion in the underwater environment can be virtually stopped. It is also possible that submerged UXO and MEC can develop a coating consisting of biological materials that can seal the item off from the environment (as well as make it more difficult to locate.)[138]

Corrosion of steel casings can produce a complex local environment composed of intact steel and iron oxidation and reduction products through which the munition constituents must pass to enter the environment. Recent studies have shown that the presence of metallic iron can strongly affect the fate and transport of munition constituents in underwater environments. This process can lead to certain munition constituents, such as RDX, being removed from solution through chemical reduction unless a source, such as a ruptured casing, continues to release the constituents to the underwater environment. The effects of the presence of iron and steel on the fate and transport of

[137] J.M. Brannon, et al. *Conceptual Model and Process Descriptor Formulations for Fate and Transport of UXO*. USACE WES, February 1999.

[138] Note that in deeper waters where residence time and turnover are measured in decades or centuries, anaerobic conditions exist that tend to preserve items.

munition constituents should be investigated further to determine the rate and extent of these effects on releases in an underwater environment.[139]

9.1.4 Environmental Fate and Transport of Munitions Constituents

The major pathways of concern for releases of munitions constituents in the underwater environment are the sediments that are found on the bottom of most rivers, lakes, ponds, wetlands, and other near-shore coastal environments. These sediments support biological communities that are the food for aquatic life. The main concerns include the following:

- The continued health of the biological community and its ability to support the ecosystem.
- Potential uptake of chemicals into the plants and sea life that ultimately form part of the food chain for people and marine life.
- Munitions constituents that may be suspended in water and potentially available to humans (through dermal contact as a result of recreational use, and ingestion of drinking water) and consumption of marine life.

As shown in Chapter 3, many munitions constituents (including the most common compounds, TNT, RDX, and HMX) have been shown to be potentially toxic to aquatic organisms. However, the potential for aquatic toxicity depends both on the fate and transport mechanism at work, and the dose exposure of aquatic organisms to these constituents. There is a mounting body of evidence that suggests that the potential for aquatic toxicity is not often realized in the open water environment where often the concentration of munitions constituents will not be detectable due to a variety of factors, including advection, dispersion, diffusion, photolysis, plant update, and biotic transformation.[140] In addition, there is increasing evidence that these compounds do not bioaccumulate in aquatic tissue.

When evaluating the fate and transport of the munitions constituents and the actual potential impact of releases of these constituents on both humans and aquatic life, a variety of complex interactions between the physical and chemical properties of these chemicals must be understood. Any of these compounds can release to the aquatic environment through the same release mechanisms as they release to land. As on land, complete detonations release compounds in such small quantities that the detection of constituents in sediments or in water is not likely. However, water in the immediate vicinity of a continuing source, such as constituents leaking from a cracked or leaking MEC casing or low-order detonation, can contain the munitions constituent in measurable quantities.[141] TNT is more water soluble than RDX and HMX and is therefore more likely to be found in small concentrations in water. Since RDX and HMX have a very low water solubility, they

[139] J.M. Brannon, et al. *Conceptual Model and Process Descriptor Formulations for Fate and Transport of UXO*.

[140] Brannon, et al. *Conceptual Model and Process Descriptor Formulations for Fate and Transport of UXO*.

[141] M. Dock, M. Fisher, and C. Cumming. *Sensor for Real-Time Detection of Underwater Unexploded Ordnance.* Paper presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

are much more likely to be dispersed as small particles by currents and unavailable either through sediments (and plant uptake), or ingestion, or dermal contact in the water column.[142]

Munitions constituents differ in how easily they bind to sediments, which may then act as a source of continuing release to water, or as a source for aquatic life uptake. Since TNT is more water soluble than RDX or HMX, it is less likely to bind to sediments, and more likely to be immediately absorbed into water. However, TNT also tends to be more susceptible to photodegredation and biotransformation, particularly in shallow water. TNT's amino biotransformation products will bind to the humic acids in sediments more strongly than RDX or HMX. This tendency to bind to sediment can reduce the overall concentration of TNT's biotransformation products in water, in spite of their relatively higher water solubility compared to RDX and HMX.[143]

Bio-uptake and bioaccumulation of munitions constituents into the food chain via aquatic plants and other organisms that grown in sediments is not well understood. Recent research on phytoremediation has shown that plants can take up munitions constituents such as TNT, RDX, and HMX. These munitions constituents will also undergo some biotransformation in the plants' tissues. The Waterways Experiments Station in Vicksburg, Mississippi, has conducted research into the uptake of TNT and RDX by aquatic plants. In these laboratory studies, TNT and its degradation products were not detected, but RDX was found to accumulate in a number of plant tissues.[144]

Biotransformation products and their properties are important factors in the fate and transport of munitions constituents. Additional research is needed on the toxicity and fate of these constituents' biotransformation products and the role sediments play in binding them. In one case, toxicological and chemical studies were performed with silty and sandy marine sediment spiked with 2,6-dinitrotoluene, tetryl, or picric acid. Whole sediment toxicity was analyzed for several invertebrate species. Tetryl was found to be the most toxic of the three spiked compounds. However, the study concluded that degradation products from the spiked compounds may have played a role in the observed toxicity.[145]

Many knowledge gaps exist, including the bioavailability of munitions constituents and their biotransformation and degradation products, how these compounds might move up the food chain, and the level at which these compounds produce harmful effects in exposed organisms, including humans. Additional research should be done to evaluate the potential for human exposure resulting from bioaccumulation in the food chain.

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[142]Personal communication with Thomas Jenkins, Ph.D, of USACOE ERDC/CRREL, on February 20, 2003.

[143]Personal communication with Thomas Jenkins, Ph.D., of USACOE ERDC/CRREL, on February 20, 2003.

[144]J.G. Burken. *Phytoremediation/Wetlands Treatment at the Iowa Army Ammunition Plant*. http://www.mhhe.com/biosci/pae/environmentalscience/casestudies/case12.html.

[145]M. Nipper, R.S. Carr, J.M. Biedenbach, R.L. Hooten, and K. Miller. *Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Pore Water.* Marine Pollution Bulletin. February 12, 2002.

9.1.5 Ecological and Human Health Effects and Toxicity of Explosive Compounds and Other Munitions Constituents in the Underwater Environment

With the increased ability to detect MEC in water bodies near naval facilities, in harbors, and in water bodies adjacent to active and former ranges and training areas, concerns about the environmental contamination caused by munitions constituents and related compounds have grown.

Previous surveys that looked at munitions constituents, particularly in the sediments and pore water of Puget Sound in Washington, concluded that the studied munitions constituents were not the main cause for concern. Rather, other organic compounds, such as PAHs, PCBs, pesticides, and to a lesser extent metals, were the main causative agents of the observed toxicity.[146]

One laboratory study was undertaken to assess the potential for adverse biological effects of munitions constituents in marine sediments and pore waters. Toxicological and chemical characterizations were performed with two kinds of sediments with different grain-size distribution and organic carbon content. These sediments were spiked with munitions constituents whose selection was based on one of the following two criteria: elevated toxicity to marine organisms or presence in marine sediments near naval facilities. The study measured concentrations of munitions constituents in the spiked sediments and corresponding pore waters and, when possible, identified degradation products.[147]

A significant conclusion of this study was that the observed toxicity did not appear to be entirely the result of the spiked compounds. The data seemed to suggest that degradation products could have played a major role in the toxicity tests. The study concluded that the actual degradation products and their persistence in the underwater environment need to be studied further and identified.[148]

A review of a number of online toxicological databases (IRIS, ATSDR, CHPPM WTAs, TOXNET) provided some information regarding ecological toxicity of a number of munitions constituents. The information in these databases seems to be incomplete in a number of areas. For example, one study stated that it appeared RDX did not bioaccumulate in food crops or in deer or cattle. (However, see 9.1.4) Another study stated that it was not known if HMX accumulated in plants, fish, or animals in contaminated areas. It is clear that additional research is needed in this area. Additional toxicological information on a number of munitions constituents, including TNT, RDX, and HMX is found in Section 3.4.

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[146]R.S. Carr, R. Scott, and M. Nipper. *Development of Marine Sediment Toxicity Data for Ordnance Compounds and Toxicity Identification Evaluation Studies at Select Naval Facilities.* Naval Facilities Engineering Service Center, Port Hueneme, CA. February 26, 1999.

[147]Nipper et al. *Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Pore Water.*

[148]Ibid.

9.1.6 An Example Conceptual Site Model

As discussed in Section 7.4, a CSM is needed in order to have a working hypothesis of the sources, pathways, and receptors at a site undergoing investigation. The CSM guides the investigation. An example of a CSM, created for the Southern Offshore Ordnance Sites, Former Mare Island Naval Shipyard, is provided in Figure 9-2.[149]

The Department of the Navy developed the CSM to examine historical site operations and previous investigations and to identify current data gaps. This CSM, which will form the basis for future MEC site investigations, covers the offshore areas of the South Shore and Ordnance Production areas located on the south and southeast end of Mare Island, respectively.

9.2 Detection of Underwater MEC

Everything is more difficult underwater!

The challenges of conducting an underwater munition detection survey include the properties of the water, the need to maintain safe working conditions, and the ability to accurately locate and retrieve the detected items. Saltwater is very corrosive, particularly in shallow water which has a higher oxygen content. Instruments exposed to the saltwater must be properly sealed. When the munition detection instrument is a hand-held detector, precautions must be taken to seal instruments by taping a plastic bag over the electronics and keeping the electronics above the water. Using instruments that are factory sealed and designed for the underwater environment, such as White's Surfmaster II and the Geonics EM-61 coils encased in epoxy with underwater connectors, is strongly recommended.[150]

Underwater munition survey work has typically required the use of divers, which presents safety problems not encountered on land. For example, blast impacts carry further underwater than they do on land for an equivalent amount of net explosive weight. The average safe distance from an underwater detonation can be over five times that of a land detonation.[151] Searching underwater for MEC is very time consuming as divers swim search patterns and mark any anomalies located. The use of more modern deployment systems on surface or submerged vehicles has its own difficulties. The issues include the potential increase in distance between the sensor and the anomaly as the water depth increases, as well as the constant movement occurring in the water environment. The variability in the depth at which MEC items may be located beneath the surface may cause an effective sensor system to become ineffective a few feet away, as the water depth increases, because of the sensor's decreased ability to detect an anomaly as the distance from sensor increases. The instability of the underwater environment, due to currents, tides, and wave action, can increase the difficulty in detecting anomalies. As on land, MEC items need to be located individually. However,

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[149] *Draft Conceptual Site Model for the Southern Offshore Ordnance Sites, Former Mare Island Naval Shipyard.* Prepared for: Department of the Navy, Commander, Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. July 17, 2002.

[150] Edwards, D. and R. Selfridge. *Munition Item Detection Systems Used By The U.S. Army Corps of Engineers in Shallow Water Environments.* U.S. Army Corps of Engineers, Huntsville Engineering and Support Center. February 12, 2003.

[151] The actual evacuation distance is based on the net explosive weight of the ordnance item.

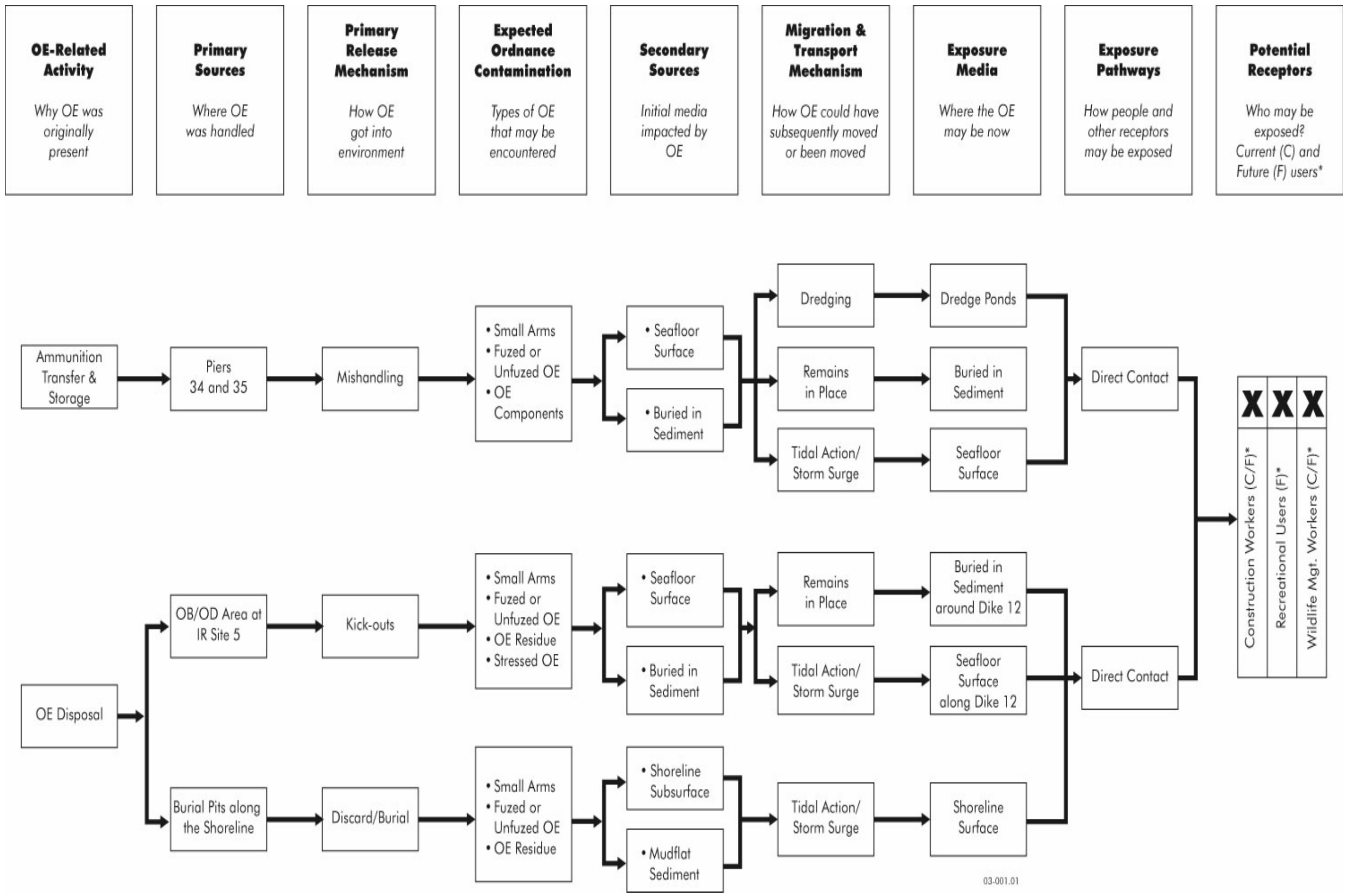

Figure 9-2. Example of a Conceptual Site Model

the underwater environment is more unstable because of the action of waves, tides, and currents. Low visibility, sedimentation, and biological and mineral coatings on the items of interest also make identifying MEC much harder. Boats and divers also have greater difficulty maintaining and marking their position. In spite of otherwise good weather conditions, work often must be stopped because of safety considerations related to wave action. In addition, underwater currents, wave action, and tides can cause underwater MEC to change location or become buried by sediment.

9.2.1 Detection Technologies

The two most common geophysical detection technologies are magnetometry and electromagnetic induction (EMI), as discussed in Chapter 4. Much of the technology used for land surveys can be adapted for underwater use. Various combinations of towed magnetometers, sidescan sonar, and underwater Geonics EM-61 can be used. (See below and the case studies in Section 9.2.4.1.) As on land, these technologies can be deployed on a variety of platforms. The selection of a particular technology, platform, data processing technique, and geolocation device for a given site often depends on the bottom conditions, the types of MEC or UXO expected, and the size of the area that is to be investigated. This is true with respect to the use of detection technologies in underwater environments.

For example, the Navy sponsored a test program at the former Mare Island Naval Shipyard (MINS) in Vallejo, California. The Naval Facilities Engineering Command, Pacific Division, contracted with a private company to perform a Validation of Detection Systems test program at MINS. The objective of the program was to identify, select, and validate detection equipment and technologies that could be used to locate and detect MEC at the four offshore sites at MINS that were suspected of containing MEC. The technical approaches included EMI and magnetometry (discussed in 4.2.1.1 and 4.2.1.2).[152]

Magnetometry is a reliable, proven technology for detecting ferrous MEC over land. With the need to detect underwater MEC increasing, a number of attempts have been made to adapt magnetometry for use underwater. An American company has developed and deployed several underwater platforms employing magnetometry in shallow water with magnetometers using a small boat as a platform. To date, they report that they have received few requests for underwater MEC exploration in the United States. Recent examples of work have included:

- Offshore sand burrows for beach replenishment on the East Coast
- Beach contamination from offshore UXO after storms on the East Coast
- Expansion and deepening of harbors in San Diego
- BRAC sites, such as at Mare Island, California
- Kaho'olawe Island, Hawaii
- Offshore pipeline routes in Hawaii[153]

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[152]Environmental Chemical Corporation (ECC). *Validation of Detection Systems (VDS) Test Program Final Report.* Burlingame, CA. July 7, 2000.

[153]R.J. Wold. *A Review of Underwater UXO Systems in Europe*. Paper presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

With respect to EMI, operating a system underwater presents at least two basic challenges. The first is the presence of water itself, particularly saltwater, which is very corrosive, and second is the inherent difficulty of controlling and tracking a sensor array. The high electrical conductivity of saltwater limits the penetration of electrical and electromagnetic energy. There are also challenges in producing the primary field and measuring its decay. To detect objects underwater, it is necessary to reduce the distance to the target by submerging the sensor. The sensor is either dragged along the bottom or "flown" above the bottom. This creates the problem of knowing the location of a sensor that cannot be seen.[154]

Both magnotometry and electromagnetic induction have problems when deployed in the marine environment. For example, magnetometers are very sensitive to distortions in the earth's magnetic field caused by the iron and steel in MEC items. Magnetometers can sense these distortions to greater depths than other systems. They also can detect small anomalies. However, magnetometers are susceptible to the magnetic signature of non-MEC items, such as the hulls of passing ships and iron and steel debris such as discarded anchors, as well as geologic noise from certain mineral deposits. In addition, the corrosivity of the underwater environment, particularly in shallow saltwater where more oxygen is available, causes the iron and steel components of MEC to corrode, reducing the magnetic signature.

Electromagnetic induction systems also have a number of problems. The electrical conductivity of water limits the penetration of electrical and electromagnetic energy. In time-domain systems, such as the Geonics EM-61, the signal decay occurs at a slower rate than on land, and the time gates of the system must be adjusted accordingly. Operation in sea water, with its high salinity, can cause a high power draw, which makes a large supply of batteries necessary.[155]

9.2.2 Platform, Positioning, and Discrimination

The three common operational platforms for deploying MEC sensors are man-portable hand-held, towed-array, and airborne (see Section 4.2.3). The methods of underwater deployment are similar. Hand-held sensors are used by divers swimming along a search pattern. Towed arrays containing several magnetometers can be pulled along the bottom. Arrays can also be suspended from an underwater mast or other device and "flown" along, either at a fixed distance below the surface of the water or at a fixed distance above the bottom. In the near-shore areas, detectors can be affixed to floating platforms as well.[156]

Positioning techniques vary depending on the platform employed. The simplest means of identifying the position of an anomaly is similar to the land-based "Mag and Flag." The anomaly position is marked by or in relation to a buoy. Arrays employ differential global positioning system (DGPS) to mark the position of any anomaly. More sophisticated platforms will also use a high-frequency echo sounder to accurately record the distance between the sensors and the bottom.

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[154] P. Pehme, Q. Yarie, K. Penney, J. Greenhouse, and D. Parker. *Adapting the Geonics EM-61 for UXO Surveys in 0-20 Metres of Water.* Paper presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

[155] Ibid.

[156] Wold. *A Review of Underwater UXO Systems in Europe*.

A number of factors affect the ability to discriminate between MEC and non-MEC. These include the instruments used, the platform, and the depth of the water over a target. For magnetometers, the apparent size of the anomaly depends on the elevation of the sensor above the anomaly. Thus, when interpreting the data, the depth of the anomaly must be taken into account. Two issues must be considered: (1) distance from the sensor to the sediment-water interface, and (2) distance of the anomaly below the sediment-water interface. The water depth above the sediment-water interface changes because of bottom topography, tides, and water level changes in rivers caused by floods and drought. For EMI, both the distance between the receiver coils and the anomaly and the separation between the transmitter and the receiver coils must be accounted for in the interpretation. In many cases, the instrument will not be able to determine the size or number of targets.

When the depth of the smallest object under investigation is within the detection limit of the sensor, the preferred platform is the surface of the water. In that situation, the attitude of the sensor is observable, the elevation of the sensor above the water bottom is known or can be determined, and the sensor position is easily measured using a GPS. However, wave action will significantly affect the attitude and the stability of the surface sensor and therefore the detectability of MEC. For anomalies approximately the size of a 12-pound MEC item, the depth limit (water depth and distance below the bottom sediments) is approximately 1.5 to 2 meters for a typical magnetometer or EMI instrument.[157]

At depths of approximately 2 to 4 meters, the geophysical sensors can be placed on a partly or fully submerged platform. This platform is rigidly linked to the watercraft, whose position is monitored by GPS. An alternative arrangement is to attach the GPS antenna to a bottom-holding system.[158]

At depths greater than 4 meters, controlling and measuring the depth and position of a submerged platform becomes more difficult. The depth to the bottom of a bottom-holding platform can be estimated by triangulation based on the measured water depth and the length of a towing cable. If the platform is flown above the bottom, controlling and monitoring the distance between the bottom and the platform's sensors are more difficult. The interpretation of an anomaly's size and depth can be strongly influenced by the indeterminate elevation of the platform sensors.[159]

Unlike land surveys that use various towed arrays, underwater surveys and equipment can be severely affected by the weather. Wave conditions, even on an otherwise good weather day, can cause serious safety concerns as well as place significant stress on a towed array. An array that is designed to handle the drag while being pulled in calm water can crumple under the additional stress created by waves.

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[157]Pehme, et al. *Adapting the Geonics EM-61 for UXO Surveys in 0-20 Metres of Water*.

[158]Ibid.

[159]Ibid.

9.2.3 Use of Divers for Detection

The oldest technology used to search for MEC underwater is manual searching using divers. Land-based searches involve technicians walking a search pattern and (usually) using a sensor. The only difference in the underwater environment is that the technician is a diver who conducts a visual and instrument-guided search. The instrument is normally hand-held. The search pattern is usually a grid marked out by a set of buoys or an expanding circle with a single buoy anchoring the center of the circle.

9.2.4 Other Technological Approaches for Detecting Underwater MEC and UXO

Magnetometers and EMI instruments can both be adapted for use in the underwater environment. For example, a variety of approaches have been developed to deploy cesium magnetometers for surveying harbors, lakes, rivers, swamps, and tidal regions. One German company is developing a system to tow a cesium sensor array in a 500-meter-deep lake to locate toxic gas containers and UXO.[160]

In the paper *A Review of Underwater UXO Systems in Europe*, presented at the 2002 UXO/Countermine Forum, it was noted that all groups that provide commercial underwater MEC/UXO surveys in Europe used arrays of magnetometers. The study did not report on any use of EMI sensors. Side-scan sonar often is used to map the bottom. Three approaches used for deployment of the magnetometer sensor arrays include suspending the array at a fixed depth, towing along the bottom, and maintaining a fixed distance above the water bottom or at a fixed depth. For data processing and analysis, visual interpretation of the data was shown to be the best way to detect UXO.[161]

The following section presents three case studies, one of an underwater towed-array magnetometer, the second of a modified Geonics EM-61, and the third of the test program. The case studies were conducted to survey underwater MEC/UXO under live conditions.

9.2.4.1 *Case Studies*

Case Study 1: Use of Hand-Held Detectors

A shallow-water procedure for USACE munition clearance projects is analogous to the "Mag-and-Flag" procedures used on land. Grids are set up and surveyed with a hand-held detector. Two projects where this process has been performed in shallow water of 3 feet or less are Buckroe Beach and the Former Erie Army Depot.[162]

In 1992, a UXO clearance was conducted at Buckroe Beach in Hampton, Virginia, along the beach and to a depth of 3 feet below the surface of the water. A systematic search of the surf zone used a procedure for laying out grids using weighted ropes and then sweeping the lanes. Five-man

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[160] Wold. *A Review of Underwater UXO Systems in Europe*.

[161] Ibid.

[162] Edwards and Selfridge. *Munition Item Detection Systems.*

teams used underwater all-metal detectors to locate ordnance in the subsurface bottom to a depth of 6 to 12 inches. Using this search method, live projectiles and expended ordnance items were successfully detected and recovered.

In 2002, a beach and shallow-water area survey at the former Erie Army Depot along the shore of Lake Erie southeast of the mouth of the Toussaint River was conducted. A total of 29 grids along the beach were cleared. The grids were 200 feet wide and extended 200 feet toward the lake until 3 feet of water was reached. Hand-held magnetometers were used to identify potential munition items. After an item was identified, its position and identification data were loaded into a data logger. Fuzed items were remotely moved to the beach with ropes and pulleys.

Case Study 2: Use of a Towed-Array Magnetometer

In a presentation at the 2002 UXO/Countermine Forum, an American company reported on the efforts of several European companies conducting commercial UXO services in Europe.[163] One such effort was a survey of a harbor on the Gulf of Bothnia, where the ship channels and turnaround areas of the harbor were being deepened. At the beginning of the dredging project, it was discovered that a significant UXO problem existed. UXO ranging from 37 mm items to 500 kg bombs were found in the harbor bottom. In some cases, whole crates of munitions were found.

A company from Finland conducted a magnetometry survey of the harbor. The base configuration consisted of four cesium magnetometers spaced 1.8 meters horizontally. The conditions of the harbor bottom did not permit the magnetometer sensor array to be towed along the harbor bottom. Two approaches to suspend the magnetometer sensor array above the harbor bottom were tried. The first approach used a 3- by 4-meter raft to tow the magnetometer sensor array, which was fixed to an aluminum wing. This approach worked well and is still used when the depth of water does not exceed 20 meters.

A second approach involved the use of a 6- by 12-meter aluminum raft supporting the magnetometer sensor array on a cross piece connected to two plastic vertical supports. The magnetometer sensor array can be fixed to a maximum of 17 meters below the raft. An altimeter and x and y accelerometers are located in the center of the cross piece. Differential global positioning system track coverage is displayed for the operator and on the bridge of the raft. A magnetic base station and GPS reference station are operated onshore. The raft travels at 2 knots, and the magnetometers take 10 readings per second. The line spacing is 5 meters.

The magnetic data, coordinates from Differential global positioning system, and the high-frequency echo sounder data are recorded to a computer. Preliminary data processing is done in the field. The onshore magnetic base station is used to compensate for the natural variations of the Earth's magnetic field. The differential correction applied to the GPS data is done using the GPS base station data and Ashtech's PNAV program. GTK's own programs and Geosoft Oasis Montaj are used for data control and processing. The magnetic total field data are filtered by bandpass filter (1-30 or 3-30 m) to remove the effects of geological formations and measurement noise.

[163] Wold. *A Review of Underwater UXO Systems in Europe.*

The GTK survey reported that for detecting all MEC and UXO, visual interpretation proved best for evaluating the data. The magnetic profiles of the four sensors are studied simultaneously. To locate the targets, GTK technicians compared the measured anomalies with the results obtained from test bomb measurements. Since the size of the magnetic anomaly depends on the elevation of the magnetic sensor, the depth to target must be taken into account during interpretation. The report's conclusions did not discuss the actual success of the harbor survey.

Case Study 3: Use of Modified EM-61

In an EMI survey conducted offshore at Dartmouth, Nova Scotia, project technicians modified the Geonics EM61-MK2.[164] Peak transmitter power in the EM61-MK2 was increased to 288 watts from 81 watts in the standard system. In addition, the frequency of the transmitter pulse was doubled and made bipolar. The standard EM61-MK2 has a unipolar transmitter pulse. This combination results in a transmitter dipole moment of 1,248 Am^2 versus the standard 156 Am^2. This modification enabled the sensor to detect deeper objects. Another modification increased the dipole moment on the transmitter loop. Further modifications were considered in order to overcome the problem of detecting very deep anomalies.

To detect the very deep anomalies, it was necessary to get the receiver closer to them. Numerous designs were modeled and tested. These tests resulted in dropping the requirement that the receiver coil have a fixed offset from the transmitter coil. This change allowed the transmitter to be maintained on a stable surface platform while varying the receiver position to allow it to get as close as possible to the target anomalies. The advantage of this modification is that the transmitter at the surface is on a stable platform that could be accurately positioned. The disadvantages include the difficulty in knowing the position of the receiver and the variability of the distance between the transmitter and the receiver, making the comparison and analysis of anomalies more difficult. This modification could detect accumulated metal on the bottom but did poorly at resolving and interpreting individual anomalies.

A reconnaissance survey was conducted to outline the general distribution of UXO resulting from a 1945 fire and explosion at Rent Point, CFAD Bedford, Canada. This reconnaissance survey required the instrument to operate from the shoreline to a depth of greater than 15 meters. In water less than 2 meters deep, the survey used a simple configuration consisting of a standard high-power EM61-MK2 with modified time gates on a raft. Where the water depth was greater than 2 meters, the modification was as follows: The primary field was created by a 5- by 8-meter transmitter coil floating on the surface. A 1- by 1-meter receiver coil was suspended below the transmitter and at a depth approximately 2 meters above the bottom. The system was combined with a digital echo sounder on the towing boat and real-time GPS mounted on the transmitter coil for positioning.

The results of the reconnaissance survey were fairly good. The system for shallow water produced good detection capabilities. The deep-water system was able to detect small objects at intermediate depths and accumulations of objects at greater depths. Because the elevations of the transmitter and the receiver above the seabed could not be accurately controlled, no attempt was made to identify and compare the size of the targets based on the amplitude of their anomalies.

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[164]Pehme, et al. *Adapting the Geonics EM-61 for UXO Surveys in 0-20 Metres of Water*.

However, additional research to improve anomaly discrimination and to better assess the size of the target is planned.

Case Study 4: Mare Island Naval Shipyard Validation of Detection Systems Test Program

The Department of the Navy identified seven sites (four offshore and three onshore) at the former Mare Island Naval Shipyard (MINS) in Vallejo, California, that potentially contained MEC. The Naval Facilities Engineering Command, Pacific Division, contracted with Environmental Chemical Corporation (ECC), Burlingame, California, to perform a Validation of Detection Systems (VDS) test program at MINS.[165]

The VDS test program was performed over a 5-week period beginning on August 30, 1999. The objective of the program was to identify, select, and validate detection equipment and technologies that could be used to locate and detect MEC at the four offshore sites at MINS. Secondary objectives of the VDS test program included the following:

- Determine which types and models of subsurface investigative instruments are successful underwater.
- Quantify the detection capacity of the equipment, attempting to obtain a 0.85 detection rate with a 90 percent confidence level.
- Quantify the false alarm ratio (FAR), attempting to minimize it.
- Determine the detection capabilities for each equipment type and system used, providing detection capabilities for each type and system in specific detection scenarios. Scenarios will exercise detection capabilities based on target composition, density mass, and depth below bottom surface.
- Determine the capabilities of the equipment to accurately match underwater geophysical anomaly data to physical reference points, either through DGPS or through other tracking and mapping techniques.
- Demonstrate that underwater anomaly data can be recorded for subsequent post-processing and analysis.
- Demonstrate that the anomaly data collected can be used to reacquire targets.

The program tested vendors' systems to determine which systems had a total probability of detection rate of at least 0.85 or higher with a 90 percent confidence level. Since more than 250 underwater targets would be required to establish a total confidence level of 90 percent, ECC decided to use only as many targets as necessary to establish the probability-of-detection goal of 0.85. The test program succeeded in evaluating and differentiating between technologies in order to determine the strengths and weaknesses of each. The VDS test results show that two vendors had the most success in detecting underwater targets. One vendor's detection system consisted of an underwater version of the Geonics EM-61 with a single coil. The second vendor's detection system was made up of two systems: a magnetic system using a four-sensor array consisting of Geometric G- 858 cesium vapor magnetometers that provide initial location data, and an electromagnetic system employing a single GEM-3 sensor that further characterizes the data set. The VDS results showed that the vendor using the Geonics EM-61 with a single coil was able to meet and exceed this

[165] ECC. *Validation of Detection Systems.*

goal with a detection rate of 0.99. The second vendor, using the combination system described above, barely missed this goal with a detection rate of 0.84.

Another objective of the test program was to minimize the FAR. The combination system with a FAR of 7 percent had the lowest of the five test participants. The Geonics EM-61 with a single coil was second, with a FAR of 18 percent. Both results show very strong detection capability.

Case Study 5: Use of a Helicopter

Airborne platforms can be successfully employed to detect underwater UXO under certain circumstances. One such effort was conducted in March 2002 using a helicopter geophysical survey to detect and map UXO at the site of the former Camp Wellfleet in Massachusetts.[166] The survey was done in an area that is now encompassed by the Cape Cod National Seashore. It was carried out with the Oak Ridge Airborne Geophysical System (ORAGS) Arrowhead magnetometer array. ORAGS consists of an eight-magnetometer array with sensors mounted in three booms (port, forward, and starboard). This arrangement is shown in Figure 9-3, has two sensors in each lateral boom and four sensors in the arrowhead-shaped forward boom. A fluxgate magnetometer is mounted in the forward boom to compensate for the magnetic signature of the aircraft. A GPS electronic Navigation system, using a satellite link, provided navigation for the survey. Differential post-processing produced more accurate positioning of the geophysical data. Altitude was measured with a laser altimeter. Over the beach and surf zone, where vegetation was low or absent, sensor heights of 1 to3 meters above ground level were regularly attained. Aircraft ground speed was maintained at approximately 12 meters per second, or 27 miles per hour. The GPS and diurnal monitor base stations were established at the airport in Hyannis, Massachusetts, at a known geodetic marker. Figure 9-4 is an orthophoto of the north beach area with targets indicated. Figure 9-5 is the corresponding magnetic map of the analytic signal.

Figure 9-3. Airborne Geophysical Survey Helicopter Platform (from Oak Ridge National Laboratory, 2002).

[166]Edwards and Selfridge. *Munition Item Detection Systems.*

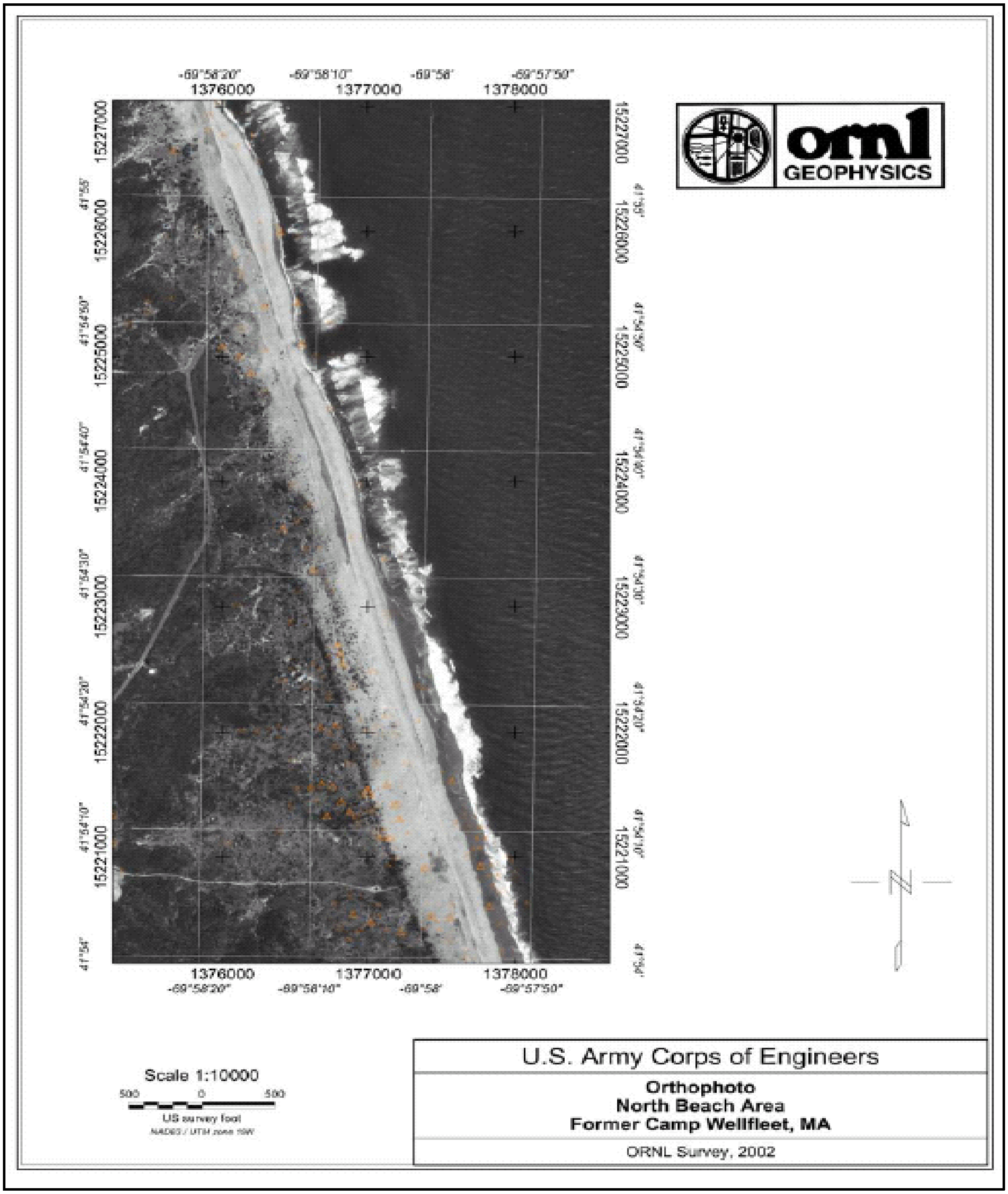

Figure 9-4. Orthophoto of North Beach Area, Former Camp Wellfleet, Massachusetts, with Detected Targets Indicated with Orange Triangles (from Oak Ridge National Laboratory, 2002)

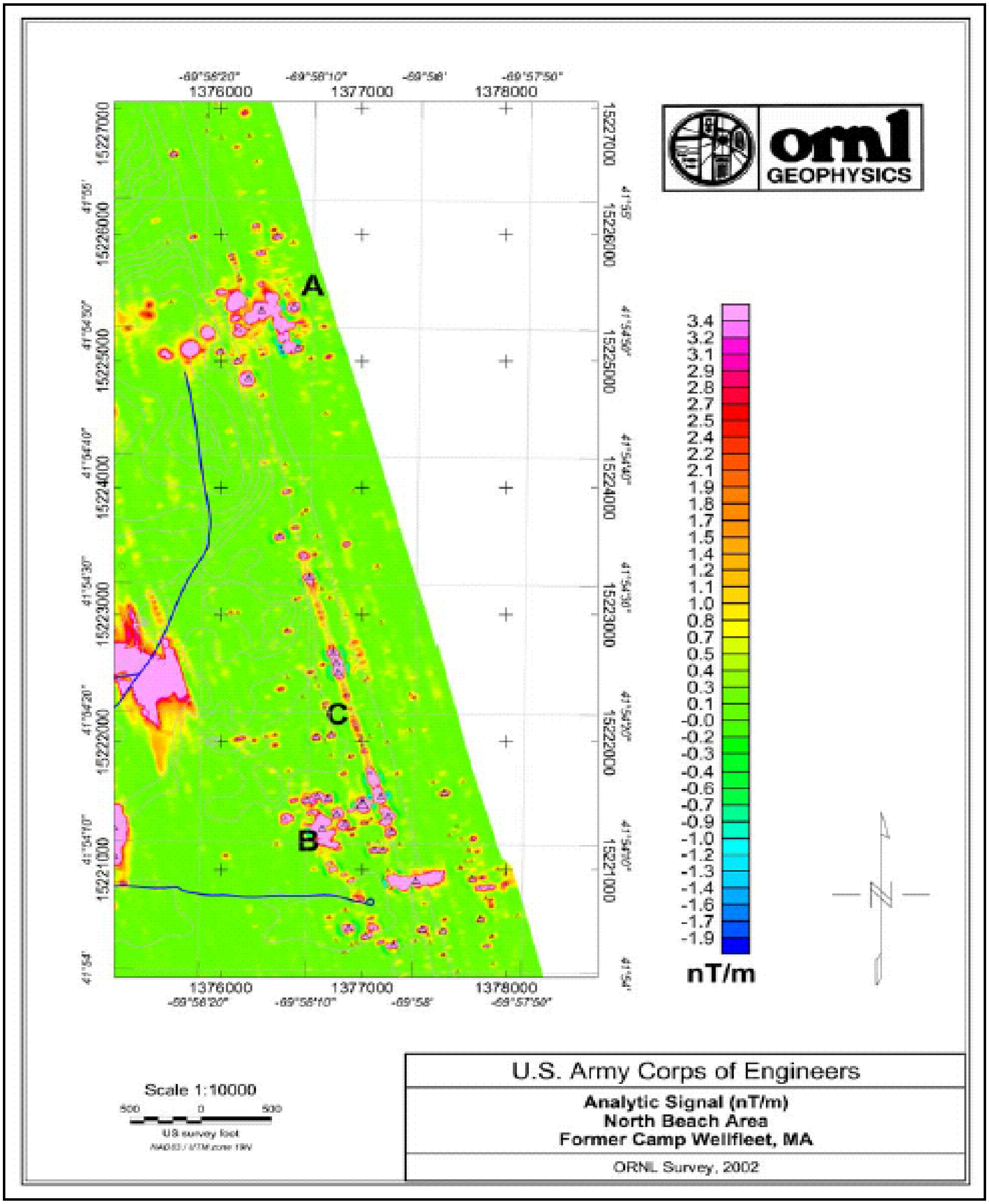

Figure 9-5. Map of the Analytic Signal of North Beach Area, Former Camp Wellfleet, Massachusetts (from Oak Ridge National Laboratory, 2002)

9.2.4.2 *Mobile Underwater Debris Survey System*

Among the potential detection technologies under development is the Mobile Underwater Debris Survey System (MUDSS), a Multisensor, towed, underwater MEC detection and identification system. MUDSS works by combining magnetic, sonar, trace chemical, and electro-optical identification sensor (EIS) technologies in a submersible, torpedolike vehicle that feeds high-speed data to a "mothership" through a fiber-optic cable.[167]

MUDSS was demonstrated during a UXO survey of a region of Choctawhatchee Bay in Florida that is adjacent to a World War II practice bombing range. The test, which was funded by the Strategic Environmental Research and Development Program (SERDP), was conducted during a 5-day period in November 1998. MUDSS was deployed from a surface vessel over a 2-square-mile shallow area (15- to 30-foot depth). Researchers traced a set of 92 parallel search tracks across the survey region. The search tracks were surveyed using a high-frequency/low-frequency (HF/LF) synthetic aperture sonar (SAS) sensor and a magnetic gradiometer array sensor to detect and locate the position of potential UXO targets. Potential targets were tagged with GPS coordinates. The MUDSS survey plan was to then reacquire nonburied targets and collect an EIS image of each target to determine whether the target was UXO. Buried targets were later investigated by divers using hand-held magnetic sensors. The divers also collected sediment samples near the confirmed buried targets to determine the presence of trace munition constituents.[168]

The MUDSS calibration tests on planted targets (ranging from a 60 mm mortar projectile to a 1,000-pound bomb) demonstrated that the HF/LF SAS, magnetic array, and EIS successfully detected and imaged calibration targets at ranges consistent with environmental conditions that included poor water clarity. MUDSS analysis of sonar and magnetic sensor survey data showed most bomblike targets were buried. Of the 492 buried magnetic targets detected, 135 targets had magnetic size and orientation consistent with UXO. This meant that MUDSS was able to eliminate 357 items as not being UXO. Eighteen of the 135 remaining targets were selected as the best targets for diver verification.[169] Using hand-held sensors, the divers were able to excavate and confirm that one target was a 500-pound bomb that was UXO and two targets were not UXO. The remaining anomalies investigated were not confirmed because of either the burial depth or the divers' inability to reacquire the anomalies using hand-held sensors.[170]

Only three suspected UXO targets had potential UXO-like acoustic signatures. Divers were unable to verify these as being UXO. The explanation offered was that the UXO bombs were buried too deeply in Choctawhatchee Bay for the sonar to detect them. Poor underwater visibility resulted in no UXO detection by the EIS.[171]

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[167]D.C. Summey. *MUDSS UXO Survey at Choctawhatchee Bay, FL.* Partners in Environmental Technology. Poster No. 80. Presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

[168]Ibid.

[169]Ibid.

[170]D.C. Summey, J.F. McCormick, and P.J. Carroll. *Mobile Underwater Debris Survey System (MUDSS).* ND.

[171]Ibid.

The researchers presented the following conclusions:

- The Choctawhatchee Bay tests confirmed the need for the MUDSS multiple sensor approach. For very difficult underwater environments, the use of multiple sensors to evaluate potential UXO targets increases the potential for identifying UXO.
- MUDSS potentially reduces the time and resources required to survey unknown underwater sites that contain MEC.
- Additional analysis of the Choctawhatchee Bay data is needed to evaluate the effectiveness of MUDSS' full system capabilities, including the EIS.[172]

Additional testing and development of this system is expected to improve its ability to successfully locate submerged and buried MEC items.

9.2.4.3 *Chemical Sensors*

One of the problems associated with the use of magnetometry and EMI is the difficulty associated with distinguishing between iron-containing debris and actual MEC or UXO items. This situation can slow the remediation of an underwater UXO site because the identity and status of each anomaly must be confirmed. This procedure can be very time-consuming and cost-intensive. An experimental approach is being investigated that seeks to identify the chemical signature of individual munition constituents, such as TNT, underwater in real time.[173]

The source of munition constituents in underwater environments is either UXO or munitions items that have undergone low-order detonation, "bleed out" of intact or damaged munitions, or disposal of bulk material. The chemical signatures of individual munition constituents can be used to determine the presence and location of munition or UXO items. The chief problems associated with detecting the chemical signatures include dilution, the variety of naturally occurring substances, and particulate matter underwater. To overcome these problems, any sensor used must have very finely defined sensitivity to measure very low (< 1 ppb) concentrations and the ability to discriminate between the target munition constituent and other potentially interfering substances.[174]

9.3 Safety

Underwater environments magnify some of the problems identified in Section 6 ("Explosives Safety") with respect to both human and ecological receptors. The primary threat to safety is the increased danger posed by an underwater detonation. The average safe distance from an underwater detonation can be over five times that of a land detonation for an equivalent amount of an explosive mixture.[175] Whereas the dangers posed by a land detonation include fragmentation, debris, and the shock wave, the danger posed by an underwater detonation is primarily from the shock wave.

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[172]Ibid.

[173]Dock, et al. *Sensor for Real-Time Detection of Underwater Unexploded Ordnance.*

[174]Ibid.

[175]The actual evacuation distance is based on the net explosive weight of the ordnance item.

The underwater environment is generally more unstable to work in than on land because of the action of waves, tides, and currents. Low visibility, sedimentation, and biological and mineral coatings on MEC items also make identification much harder. For example, determining if a potential UXO item is fuzed and armed, or what type of fuze or fuzes are present, can be nearly impossible.

Because of the danger posed by an underwater detonation, divers must be out of the water before moving any MEC or UXO item or attempting to blow it in place. Current practices are costly and time-consuming. Technologies that rely much less on divers need to be developed so that underwater remediation is safer and more cost-effective.

9.4 Underwater Response Technologies

9.4.1 Blowing in Place

The most common technique for dealing with UXO is in-place open detonation, also known as blowing-in-place (BIP). However, BIP is hazardous to humans in the water and to aquatic life, as well as harmful to sensitive environments, such as wetlands and coastal marshes. It is necessary to coordinate with Federal, State, and local regulatory officials to obtain approval for BIP, as marine biota, such as sea turtles and marine mammals, may be affected at substantial distances from an underwater detonation.

The rapid shockwave pressures associated with underwater detonations can cause adverse biological effects. The primary blast injury in marine mammals and sea turtles, other than death as a result of the underwater detonation, has been shown to be to the auditory, respiratory, and gastrointestinal organs. Depending on water conditions, sound travels further underwater than the pressure wave generated by the detonation.[176]

BIP may be necessary because of the hazardous nature of the UXO. One technique to mitigate the effects of BIP involves the use of low-order instead of high-order detonation. A low-order detonation is any explosive yield less than high order. Planning to conduct low-order detonations must include the possibility of a high-order detonation. The reduction in explosive yield depends on a number of factors, including but not limited to, the type of ordnance, explosive fill, detonation tool, and technique.

Detonation Tools

Low-order detonation tools are designed to transmit sufficient energy to an MEC/UXO case to rupture it without causing a full detonation reaction in the explosive charge.

The availability of low-order detonation technologies has increased, providing potential alternatives to traditional BIP procedures for surface MEC. Low-order detonation tools are designed to transmit sufficient energy to an MEC case to rupture it without causing a full detonation reaction in the explosive charge. It is possible in some cases to reduce the explosive yield of a large MEC item by up to 90 percent. However, a consequence of low-order detonations may be the release of significant amounts of munition constituents into the underwater environment. These releases must

[176] *Mitigation Options for Underwater Explosions.* Prepared for the Naval Undersea Warfare Center, Waianae, HI. September 19, 2000.

be accounted for and managed in underwater response activities. Research is being conducted in the application of low-order BIP as a response action that reduces the effect on underwater environments.[177]

One low-order detonation tool, called HL21, was developed in Germany. The HL21 uses a shaped charge to rupture the UXO casing and has been used successfully on surface UXO. Tests of the system were conducted in water-filled 55-gallon drums that contained 155 mm TNT-filled, nonfuzed projectiles. In five trials, the low-order detonation of 155 mm projectiles generated large fragments and small amounts of TNT.[178] Further testing is planned.

Another technique to mitigate BIP involves using physical barriers. Sandbags, concrete blocks, or other barriers can be used to surround the MEC item. The barrier can be formed to focus the sound and shock waves upward, reducing lateral effects. This technique is likely to work only in shallower water, as there are practical limits on the height of a barrier constructed underwater.

9.4.2 Dredging

Dredging can be a cost-effective and productive method for removing underwater MEC. Dredging excavates large areas and does not require detection or positioning of each MEC item. However, removing MEC by dredging is not necessarily a precise process and presents risks from both detonation of MEC and exposure to munition residues. Sediment turbidity inhibits visual verification of MEC removal, so monitoring the dredge discharge may be necessary. Dredging can also leave some MEC behind. Most of the MEC left behind will be on the newly dredged surface, and some of these MEC items can become mobile.[179] Additionally, dredging only transports potential MEC from one place to another. The dredge spoils potentially containing MEC may also require a munitions response action. Consideration should be given to offshore location and depth in determining whether MEC contained in offshore sediments pose a significant threat to human health and the environment.

Hydraulic and mechanical dredging methods vary in cost, effectiveness, and safety. Hydraulic dredging may be more productive and cost-effective for removing material that does not contain concentrated, highly sensitive, or large MEC items. Mechanical dredging is suitable for sensitive and large MEC items, and it may provide increased removal reliability. Engineering protective measures or the use of remotely operated equipment must be implemented to ensure worker safety. However, mechanical dredges are not appropriate for removing large areas of material because of their low productivity. A hybrid approach for removal of sensitive MEC items combines the benefits of the mechanical dredge's removal reliability and the hydraulic dredge's productivity. Therefore, the hydraulic dredge may be used to remove large volumes of material while rejecting or avoiding MEC. The mechanical dredge would then be used to collect the MEC from the bottom.[180]

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[177] A. Pedersen. *Low-Order Underwater Detonation.* Environmental Security Performance Report. November 2002.

[178] Ibid.

[179] Edwards and Selfridge. *Munition Item Detection Systems.*

[180] Ibid.

Dredging methods may have useful applications in UXO removal but to date have not been integrated with detection methods and means of separating metallic materials from nonmetallic materials.[181]

[181]Ibid.

SOURCES AND RESOURCES

The following publications are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications were also used in the development of this handbook.

Publications

Brannon, J.M., and T.E. Myers. *Review of Fate and Transport Processes of Explosives*. U.S. Army Corps of Engineers WES. Technical Report IRRP-97-2. March 1997.

Brannon, J.M., et al. *Conceptual Model and Process Descriptor Formulations for Fate and Transport of UXO*. U.S. Army Corps of Engineers WES, February 1999.

Carr, R.S., and M. Nipper. *Development of Marine Sediment Toxicity Data for Ordnance Compounds and Toxicity Identification Evaluation Studies at Select Naval Facilities.* Naval Facilities Engineering Service Center, Port Hueneme, CA. February 26, 1999.

Darrich, M.R. et al. *Trace Explosives Signatures from World War II Unexploded Undersea Ordnance*. Environmental Science and Technology, 32(9): 1,354-58, 1998.

Dock, M., M. Fisher, and C. Cumming. *Sensor for Real-Time Detection of Underwater Unexploded Ordnance*. Paper presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

Dow, J. *Conceptual Site Model and Risk Assessment for Underwater Ordnance Remediation*. Prepared for the third EPA/DoD CSM and DQO meeting. February 28-March 1, 2001.

Edwards, D., and R. Selfridge. *Munition Item Detection Systems Used by the U.S. Army Corps of Engineers in Shallow Water Environments*. U.S. Army Corps of Engineers, Huntsville Engineering and Support Center. February 12, 2003.

Jenkins, T.F. et al. *Characterization of Explosives Contamination at Military Firing Ranges*. U.S. Army Corps of Engineers, Engineer Research and Development Center, Hanover, NH, Technical Report ERDC TR-01-5. July 2001.

Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, and K. Miller. *Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Pore Water*. Marine Pollution Bulletin. February 12, 2002.

Pedersen, A. *The Challenges of UXO in the Marine Environment*. Naval EOD Technology Division.

Pedersen, A., and J. Delaney. *Low-Order Underwater Detonation Study*. Naval EOD Technology Division (NAVEODTECHDIV). ND.

Pehme, P., Q. Yarie, K. Penney, J. Greenhouse, and D. Parker. *Adapting the Geonics EM-61 for UXO Surveys in 0-20 Metres of Water*. Paper presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

Summey, D.C. *MUDSS UXO Survey at Choctawhatchee Bay, FL*. Partners in Environmental Technology. Poster No. 80. Presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

Summey, D.C., J.F. McCormick, and P.J. Carroll. *Mobile Underwater Debris Survey System (MUDSS)*. ND.

Thiboutot, S., G. Ampleman, and A.D. Hewitt. *Guide for Characterization of Sites Contaminated with Energetic Materials*. U.S. Army Corps of Engineers ERDC/CRREL TR-02-1. February 2002.

USACE. *Toxicity of Military Unique Compounds in Aquatic Organisms: An Annotated Bibliography (Studies Published Through 1996)*. Waterways Experiment Station (WES), Vicksburg, MS, Technical Report IRRP-98-4. April 1998.

U.S. EPA. *Health Advisory for Hexahydro-1,3,5-Trinitro-1,3,5-Triazine (RDX)*. Criteria and Standards Division, Office of Drinking Water, Washington, DC. November 1988.

U.S. EPA. *Health Advisory for Octahydro-1,3,5,7-Tetranitro-1,3,5,7-Tetrazocine (HMX)*. Criteria and Standards Division, Office of Drinking Water, Washington, DC. November 1988.

U.S. EPA. *Potential Species for Phytoremediation of Perchlorate*. Office of Research and Development, Washington, D.C. EPA/600/R-99/069, August 1999.

U.S. EPA. *Trinitrotoluene Health Advisory*. Office of Drinking Water, U.S. Environmental Protection Agency. Washington, DC. January 1989.

Wold, R.J. *A Review of Underwater UXO Systems in Europe*. Paper presented at the 2002 UXO/Countermine Forum, Orlando, FL, September 2002.

U.S. Navy. *Mitigation Options for Underwater Explosions*. Prepared for the Naval Undersea Warfare Center, Waianae, HI. September 19, 2000.

U.S. Navy. *Draft Conceptual Site Model for the Southern Offshore Ordnance Sites, Former Mare Island Naval Shipyard*. Prepared for Department of the Navy, Commander, Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. July 17, 2002.

U.S. Navy. *Technical Memorandum for Offshore OE Clearance Model, OE Investigation and Response Actions, Former Mare Island Naval Shipyard (MINS)*. Prepared for Commander, Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. February 11, 1999.

U.S. Navy. *Validation of Detection Systems (VDS) Test Program Final Report*. Mare Island Naval Shipyard (MINS), Vallejo, CA. Prepared for Commander, Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. July 7, 2000.

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10.0 CHEMICAL MUNITIONS AND AGENTS

10.1 Introduction to Chemical Munitions and Agents

Chemical munitions and agents are defined by the Department of Defense Explosives Safety Board (DDESB) as:

> *An agent or munition that, through its chemical properties, produces lethal or other damaging effects to human beings, except that such term does not include riot control agents, chemical herbicides, smoke or other obscuration materials.*[182]

The presence of chemical agents can add significantly to the complexity of an MRS site investigation. Risks include potentially lethal contamination by releases of liquid or vapor forms of the chemicals, in addition to the explosive hazards of fuses, boosters, bursters, or propellants that may exist within munitions. The presence of chemical agents and/or their degradation products may pose a threat to soil and groundwater.

> **The Chemicals in This Chapter**
>
> The lists of chemical warfare agents described in this chapter are taken from the *Convention in the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons*, Annex on Chemicals. This list does not include all of the chemicals contained in that Annex, but rather focuses on those most commonly tested in the United States.

The majority of the chemical weapons in this country are considered stockpile chemical weapons.[183] Stockpile weapons are weapons and bulk agents that could be used in a retaliatory strike against an opponent or could serve as a deterrent to such a strike. **Stockpile items are made up of chemical agents and munitions that have been maintained under proper storage and accounting procedures since their manufacture.** Under the Chemical Weapons Convention, all stockpile weapons in the United States must be destroyed by April 29, 2007, unless an extension of up to 5 years is given.

In addition to agreeing to destroy the chemical weapons stockpile, the United States also agreed to dispose of all other chemical weapons-related materiel, which are considered non-stockpile materiel. Non-stockpile chemical warfare materiel (NSCWM) consists of five categories: (1) binary chemical weapons,[184] (2) former chemical weapons production facilities, (3) unfilled munitions and devices, and chemical samples, as defined by the Chemical Weapons Convention, (4) chemical weapons already recovered from pre-1969 land disposal sites, and (5) buried CWM yet to be recovered. Such materiel exists at hundreds of locations as a result of routine disposal by burial that was conducted prior to the 1969 changes in public laws. Since it is reasonably expected that only non-stockpile chemical materiel would be found at MRSs and other defense sites, this chapter addresses only non-stockpile chemical materiel.

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[182] DoD Ammunition and Explosives Safety Standards, July 1999, Chapter 12, DoD Directive 6055.9-STD.

[183] This chapter does not address chemical weapons of foreign origin.

[184] *Binary chemical weapons* refers to the concept of developing nontoxic precursors that can be loaded in munitions. Once deployed, the precursors mix and develop the nerve agent.

Chemical agents achieve their effects through chemical actions rather than through blast, fragments, projectiles, or heat, which are normally associated with explosives. Chemical agents are characterized by the potential human health effects, which range from incapacitation to lethality. The actual effects of exposure vary with the type and concentration of the agent, form (gaseous, liquid), dose and pathway, and susceptibility of the exposed individual. Chemical agents are classified as nerve, blister, blood, choking, tear gas, and vomiting agents. Definitions for each of the classifications and their relative toxicities are discussed in Section 10.4.

Because of the overlap of detection methods, remediation techniques, and safety considerations for chemical and conventional explosive munitions, this chapter focuses on those issues that differentiate chemical munitions from conventional explosive munitions.

10.2 Where Chemical Munitions and Agents Are Found

10.2.1 <u>Background</u>

Chemical agents can be found in most types of munitions, including grenades, artillery projectiles, bombs, mines, and rockets. Chemical agents also are found in various storage containers, such as one-ton containers, PIGS and Chemical Agent Identification Sets (CAIS), that might be found at burial sites. CAIS have been routinely used in personnel training since World War I and are considered chemical warfare materiel (CWM). These may be found on any military facility where troop training was conducted. CAIS come in three principal types that contain real chemical agent in bottles or vials to be used in different types of training exercises. CAIS were used from 1928 to 1969 and were widely distributed during World War II. During the World War II era they were frequently disposed of by burial.

Containers of Chemical Agent

One-ton containers:

- Bulk cylindrical steel containers
- Hold 170 gallons of materiel
- 101.5 inches long, 30.5 inches in diameter
- Three types (A, D, and E)

PIGS:

- Cylindrical forged steel shipping container
- Used to transport and store Chemical Agent Identification Sets (CAIS) and laboratory standards
- 38 inches long

CAIS:

- Used for field training
- Kits contain glass tubes/vials of different chemical agents such as:
  - mustard (H)
  - lewisite (L)
  - phosgene (CG)
  - chlorpicrin (PS)

Seven different configurations of CAIS kits were made by the Army and Navy over a period of close to 50 years. Three principal varieties of these are still found today: (1) toxic gas sets (100 ml bottles of mustard), (2) gas identification sets (40 ml heat-sealed vials with dilute agents except for pure phosgene), and (3) Navy or sniff sets (filled with charcoal on which 25 ml of agent was placed). They were intended for use by troops during training so that different chemical agents could be properly identified and decontaminated in combat. Complete sets contained from 2 to 48 bottles or vials, depending on the type of set. Some complete sets contain small quantities of agent, while others contain as much chemical agent as is normally found in large projectiles.

Many munitions of the World War II era, such as 4.2 inch mortars, M47 and M70 bombs, Livens projectiles, 75 mm projectiles, 4 inch Stokes mortars, and others, had both lethal chemical fills and smoke and/or incendiary fills, all of which are liquid. In addition, some industrial compounds were used to produce lethal effects. These include phosgene, hydrogen cyanide, and cyanogen chloride.

10.2.2 Stockpile and Non-stockpile CWM Sites

There are two basic categories of sites containing CWM and agents which are designated on the basis of how the materiel was stored: stockpile and non-stockpile CWM sites.

Stockpile CWM sites are those locations in the United States where all chemical agents and munitions that were available for use on the battlefield (including those assembled in weapons and in bulk one-ton containers) are stored. There are currently eight locations that the United States has control of where stockpile CWM is found: Umatilla Depot, Oregon; Tooele Army Depot, Utah; Pueblo Depot, Colorado; Newport Army Munition Plant, Indiana; Aberdeen Proving Ground, Maryland; Lexington Blue Grass Army Depot, Kentucky; Anniston Army Depot, Alabama; and Pine Bluff Arsenal, Arkansas. (Destruction of CWM at Johnston Atoll has been completed.)

In 1985, the U.S. Congress passed Public Law 99-145, which requires the destruction of the stockpile of lethal chemical warfare agents and munitions in the United States. A 1997 decision to ratify the Chemical Weapons Convention required the destruction, by 2007, of all stockpiled CWM, and all non-stockpile CWM known at the time of the signing. The United States and other signatories are in the process of moving aggressively to meet this requirement. However, the United States has acknowledged difficulty in achieving this goal and has requested the allowed 5-year extension.

Non-stockpile Chemical Materiel

Non-stockpile chemical materiel includes the following categories, all of which could be located at MRSs:

- **Buried chemical materiel** – materiel that was buried between World War I and at least the late 1950s, during which time burial was considered to be a final disposal solution for obsolete chemical weapons.
- **Binary chemical weapons** – munitions designed to use two relatively nontoxic chemicals that combine during functioning of the weapons system to produce a chemical agent for release on target. (These weapons were neither widely produced nor tested in the United States.)
- **Recovered chemical weapons** – those weapons retrieved from range-clearing operations, research and test sites, and burial sites.
- **Former chemical weapons production facilities** – facilities that produced chemical agents and other components for chemical weapons.
- **Other miscellaneous chemical warfare material** – includes unfilled munitions and devices; samples; and research, development, testing, and evaluation materials that were used for the development of chemical weapons.

According to the Army's Program Manager for Chemical Destruction, as of June 8, 2003, 26 percent of the original stockpile of chemical agent in the United States had been destroyed, and 39 percent of chemical munitions had been destroyed. More information can be found on their website: http://www.pmcd.army.mil.

The second category of CWM and agents is referred to as non-stockpile chemical materiel (NSCM). This is a diverse category that includes all other chemical weapon-related items, such as lethal wastes from past disposal efforts, unserviceable munitions, and chemically contaminated containers; chemical production facilities; newly located chemical munitions; known sites containing significant quantities of buried chemical weapons and waste; and binary weapons and components.

According to the National Research Council,[185] as of 1996, the Army identified 168 potential burial sites in 31 States and several territories (including the District of Columbia). Most are current or former military facilities. The majority of sites are thought to include small quantities of material. The information reported as of 1996 is updated regularly and maintained by the Product Manager for the Non- Stockpile Chemical Warfare Materiel (NSCWM) program.

NSCWM can be found in a range of different areas. It may be found at any site that manufactured or conducted testing of chemical agent and/or weapons, stored such materials as they were prepared for shipment overseas, or provided training to troops who used CAIS kits to identify chemical agent. Since development and testing of chemical weapons took place as early as the World War 1 era, and many military test sites have either changed uses over time or have been transferred out of military ownership, such locations are not always obvious. The National Research Council has asserted that "a major uncertainty for the non-stockpile program is the extent to which suspected burial sites will be excavated and what items will be found and recovered."[186] Sites that have been transferred out of military ownership (formerly used defense sites – FUDS) may represent a particular challenge. For example, in the World War 1 era, a test site owned by American University was the location of significant testing of chemical agent material by the military. That location is now in residential use. Non-stockpile material has been recovered and destroyed in ongoing investigations and cleanup activities likely to go on for a number of years.

NSCWM in Residential Delaware

On July 19, 2004, Explosive Ordnance Disposal (EOD) personnel from Dover AFB recovered an explosive munition embedded in a driveway made of clamshell paving material. This material was dredged off the Mid-Atlantic coast. The EOD team detonated the munition with a shaped charge whereupon a black tar-like substance began to ooze from the munition. Mustard agent (HD) was detected in the tar-like substance. The next day, 3 members of the EOD team were stricken with HD-related blisters. Army records indicate that 1,700 mustard filled rounds were dumped off the coast of Cape May, NJ in 1964.

10.3 Regulatory Requirements

The regulatory authorities for managing recovered CWM (RCWM) include all of the regulations that apply to explosive munitions, as described in Chapter 2. In addition, 50 USC 1512-1521 provide specific guidance to DoD on transporting, testing, and/or disposing of lethal chemical agent. The principal regulatory programs under which cleanup of RCWM at MRSs is conducted include CERCLA, RCRA, the Defense Environmental Restoration Program (DERP), and the safety standards of the DDESB. In addition, the Army, as the single manager for conventional

[185] Systems and Technologies for the Treatment of Non-stockpile Chemical Warfare Materiel, National Research Council, Board on Army Science and Technology, National Research Council, National Academy Press, 2003.

[186] Ibid.

munitions (which includes chemical agents), has developed a number of regulations and guidance documents designed to specifically address the management of chemical agents.[187]

AR 50-6 outlines the policies, procedures, and responsibilities for the Army Chemical Surety Program, which is designed to provide tools to facilitate safe and secure operations involving chemical agents. AR 50-6 describes the policies for the safe storage, handling, maintenance, transportation, inventory, treatment, and disposal of CWM. The policy also provides safety and security control measures to ensure the safe conduct of chemical agent operations and personnel safeguards for the recovery of CWM discovered during environmental remediation activities or by chance. AR 385-61 establishes policies and responsibilities for the Army's chemical agent safety program, and DA PAM 385-61 describes the safety criteria and standards for processing, handling, storing, transporting, disposal, and decontamination of chemical agents. These chemical munitions-specific safety regulations are discussed again in Section 10.7.) Additional regulations are listed in "Sources and Resources" at the end of this chapter. In addition to U.S. regulations, disposal of CWM must also comply with the notification requirements of the CWC.

10.4 Classifications and Acute Effects of Chemical Agents

Chemical agents, such as blister, blood, choking, incapacitating, lacrimator (tear gas), vomiting, and nerve agents, are typically classified by the type of physiological action caused by exposure. A wide variety of chemical agents can be found on MRSs, either in their original form or in some deteriorated form.

The effects of these chemical agents include long-term chronic effects such as cancer or nerve damage and acute effects ranging from incapacitation to lethality. Effects vary with the type of agent, concentration, form, duration and route of exposure, and condition of the person exposed (e.g., elderly, children). All of these agents can cause death, some more quickly than others. When certain chemical agents are used in combination with each other, the speed and likelihood of lethality increases. The following sections provide an overview of the acute health effects of the different categories of chemical agents. Subsequent sections provide more detail related to chronic health effects and toxicity.

- **Blister agents** (vesicants) – work by destroying individual cells that come in contact with the agent. Blister agents, as the name implies, cause tissue damage, including blisters, on the skin and produce severe effects in the eyes and lungs (if inhaled). Compared with some of the other chemical agents, blister agents take longer to produce effects (4-24 hours) and are intended to cause incapacitation casualties for a longer duration (36 hours to several days). The following are considered blister agents:

  – Lewisite / L
  – Mustard-Lewisite Mixture / HL
  – Nitrogen Mustard / HN-1

[187]DoD Directive 5160.65, Single Manager for Conventional Ammunition, March 8, 1995. Many Army policies also are addressed in Army Regulation (AR) 50-6, *Chemical Surety*, February 1, 1995; AR 385-61, *Army Chemical Agent Safety Program*, February 28, 1997; and Department of the Army Pamphlet (DA PAM) 385-61, *Toxic Chemical Agent Safety Standards*, March 31, 1997.

- Nitrogen Mustard / HN-2
- Nitrogen Mustard / HN-3
- Sulfur Mustard Agent / H, HD or HS
- Mustard- T Mixture / Sulfur Mustard Agent / HT
- Phenyldichloroarsine / PD
- Ethyldichloroarsine / ED
- Methyldichloroarsine / MD
- Phosgene Oxime / CX

C **Blood agents** – affect bodily functions through action on an enzyme, resulting in the inability of cells to use oxygen normally. This interaction leads to rapid damage to body tissues. Blood agents are absorbed into the body through inhalation. The following are considered blood agents:

- Hydrogen Cyanide /Prussic Acid / AC
- Cyanogen Chloride / CK
- Arsine / SA

C **Choking agents** – damage the respiratory tract, especially the lungs. Affected cells in the respiratory tract become filled with liquid, and an oxygen deficiency results in choking and asphyxia. The following are considered choking agents:

- Phosgene / CG
- Diphosgene / DP

C **Nerve agents** – encompass a variety of compounds that have the capacity to inactivate the enzyme acetylcholinesterase (AChE). They generally are divided into two families, the G agents and the V agents. The Germans developed the G agents (tabun [GA], GB, and GD) during World War II. They are volatile compounds that pose mainly an inhalation hazard. The nerve agent GB is quick acting (5-10 minutes to onset of symptoms after inhalation), and very low doses may incapacitate a person for 1-5 days. The effects of higher doses include muscle contractions, suffocation, and death. V agents, which were developed later, are approximately 10 times more toxic than GB and are considered persistent agents, which means that they can remain on surfaces for long periods. The consistency of V agents is oily, thus they mainly pose a contact hazard. A highly toxic nerve agent, VX, acts by absorption through the skin and causes muscle contractions, suffocation, and death. The following are considered nerve agents:

- Tabun / GA
- Sarin / GB
- Soman / GD
- V-Agent / VX
- Cyclo-sarin / GF

- **Tear gas**[188] – irritates skin and eyes, causing short-term incapacitation. Prolonged exposure, such as in an indoor situation, can cause illness and death. The duration of incapacitation is approximately 10 minutes. Symptoms of exposure include burning eyes, tearing, and irritation of the respiratory tract. The following are considered tear gas agents:

  – Chloroacetophenone / CN
  – Chloropicrin / PS
  – Chloroacetophenone and chloropicrin in chloroform /CNS
  – Chloroacetophenone in benzene and carbon tetrachloride / CNB
  – Bromobenzylcyanide / CA
  – O-Chlorobenzylidene / CS *also* CS1 and CS2

- **Incapacitation agents** – block the action of acetylcholine both peripherally and centrally. The agent BZ, the only known incapacitation agent that is a central nervous system depressant, disturbs integrative functions of memory, problem-solving, and comprehension.

- **Vomiting agents** – induce nausea and vomiting. Physiological actions of vomiting agents include eye irritation, mucous discharge from the nose, severe headache, acute pain and tightness in the chest, nausea and vomiting. The following are considered vomiting agents:

  – Diphenylchloroarsine / DA
  – Adamsite / DM
  – Diphenylcyanoarsine / DC

10.4.1 Chronic Human Health Effects of Chemical Agents

Although CWM is most commonly thought of in relation to acute effects, chronic health effects are also significant. For example, if an exposure occurs outside the range of acute toxicity during an exposure event, or if a low level of exposure occurs due to the presence of small amounts of a particular chemical, then chronic effects such as cancer can occur.

Table 10-1 lists some of the common chemical agents and known chronic health effects. The table is organized by major category of chemical agent. Where no information on the chronic effects of a particular agent was found in readily available literature, it is noted as "not available."

Table 10-1. Chemical Agents and Their Potential Chronic Effects

Common Name	Chemical Name /Formula/CAS#	Potential Chronic Effects
Blister Agents/Vesicants		
Lewisite/L	Dichloro-(2-chlorovinyl)arsine	Chronic respiratory and eye conditions may

[188] Tear Gas is listed as a CWM when used in warfare. The U.S. implementing legislation exempts Tear gas from reporting requirements when found in concentrations of less than 80 percent.

Table 10-1. Chemical Agents and Their Potential Chronic Effects (continued)

Common Name	Chemical Name /Formula/CAS#	Potential Chronic Effects
	$C_2H_2AsCl_3$ CAS# 541-25-3	persist. Arsenical poisoning possible.
Mustard-Lewisite Mixture/HL	Not applicable (mix of components)	Chronic respiratory and eye conditions and arsenical poisoning. May produce respiratory and skin cancer.
Nitrogen Mustard/HN-1	2,2'-dichlorotriethylamine $C_6H_{13}Cl_2N$ CAS# 538-07-8	Possible human carcinogen. Chronic respiratory and eye conditions may persist. May decrease fertility.
Nitrogen Mustard/HN-2	2,2'-dichloro-N-methyldiethylamine $C_5H_{11}Cl_2N$ CAS# 51-75-2	Possible human carcinogen. Chronic respiratory and eye conditions may persist. May decrease fertility.
Nitrogen Mustard/HN-3	2,2',2"-trichlorotriethylamine $C_6H_{12}Cl_3N$ CAS# 555-77-1	Possible human carcinogen. Chronic respiratory and eye conditions may persist. May decrease fertility.
Sulfur Mustard Agent/H, HD or HS	Bis(2-chloroethyl) sulfide $C_4H_8Cl_2S$ CAS# 505-60-2	Carcinogenic to humans. May cause cancer of the upper respiratory tract, skin, mouth, throat, and leukemia. Chronic respiratory and eye conditions may persist. May cause skin sensitization. Potential teratogen.
Mustard-T Mixture/Sulfur Mustard Agent/HT	60% HD and 40% sulfur and chlorine compound CAS# 6392-89-8	Not Available
Phenyldichloroarsine/PD	Phenyldichloroarsine $C_6H_5AsCl_2$ CAS# 696-28-6	Similar properties and toxicities as lewisite.
Ethyldichloroarsine/ED	Ethyldichloroarsine $C_2H_5AsCl_2$ CAS# 598-14-1	Similar properties and toxicities as lewisite.
Methyldichloroarsine/MD	Methyldichloroarsine CH_3AsCl_2 CAS# 593-89-5	Similar properties and toxicities as lewisite.
Phosgene Oxime/CX	Dichloroformoxime $CHCl_2NO$ CAS# 1794-86-1	Not Available
Blood Agents		
Hydrogen Cyanide/Prussic Acid/AC	Hydrogen cyanide HCN CAS# 74-90-8	Similar to acute effects. Skin conditions have been reported. Long-term exposures have produced thyroid changes. Occasionally: chronic eye conditions.
Cyanogen Chloride/CK	Chlorine cyanide ClCN CAS# 506-77-4	Long-term exposures will cause dermatitis, loss of appetite, headache, and upper respiratory irritation in humans.
Arsine/SA	Arsenic trihydride AsH_3 CAS# 7784-42-1	Human carcinogen. May cause skin or lung cancer. Chronic arsenic exposure can affect skin, respiratory tract, heart, liver, kidneys, blood and blood-producing organs, and the nervous system.

Table 10-1. Chemical Agents and Their Potential Chronic Effects (continued)

Common Name	Chemical Name /Formula/CAS#	Potential Chronic Effects
Choking Agents		
Phosgene/CG	Dichloroformaldehyde Carbonyl chloride CCl_2O CAS# 75-44-5	Chronic exposure may cause emphysema, fibrosis, skin, and eye conditions.
Diphosgene/DP	Trichloromethyl chloroformate $C_2Cl_4O_2$ CAS# 503-38-8	Not Available
Nerve Agents		
Tabun/GA	Ethyl N,N-dimethylphosphoramidocyanidate $C_5H_{11}N_2O_2P$ CAS# 77-81-6	Weakness of skeletal musculature. In severe cases: disabling condition (muscle weakness and paralysis).
Sarin/GB	Isopropylmethyl-phosphonofluoridate $C_4H_{10}FO_2P$ CAS# 107-44-8	Weakness of skeletal musculature. In severe cases: disabling condition (muscle weakness and paralysis).
Soman/GD	Pinacolyl methyl-phosphonofluoridate $C_7H_{16}FO_2P$ CAS# 96-64-0	Weakness of skeletal musculature. In severe cases: disabling condition (muscle weakness and paralysis).
V-Agent/VX	O-ethyl S-[2-(disopropylamine)ethyl] methylphosphonothiolate $C_{11}H_{26}NO_2PS$ CAS# 50782-69-9	Weakness of skeletal musculature. In severe cases: disabling condition (muscle weakness and paralysis).
Cyclo-sarin/GF	$CH_3PO(F)OC_6H_{11}$	Not Available
Incapacitating Agents		
Agent BZ	3-Quinuclidinyl benzilate $C_{21}H_{23}NO_3$ CAS# 6581-06-2	Not Available
Lacrimators/Tear Gases*		
Chloroacetophenone/CN	2-Chloroacetophenone $C_6H_5COCH_2Cl$ CAS# 532-27-4	Repeated or prolonged contact may cause chronic skin conditions.
Chloropicrin/PS	Chloropicrin CCl_3NO_2 CAS# 76-06-2	Not Available
Chloroacetophenone and chloropicrin in chloroform/CNS	Mixture of CN, PS, and chloroform na	No known long-term effects
Chloroacetophenone in benzene and carbon tetrachloride/CNB	Mixture of CN, carbon tetrachloride, and benzene	Not Available
Bromobenzylcyanide/CA	Bromobenzylcyanide C_8H_6BrN CAS# 5798-79-8	Not Available

Table 10-1. Chemical Agents and Their Potential Chronic Effects (continued)

Common Name	Chemical Name /Formula/CAS#	Potential Chronic Effects
O-Chlorobenzylidene/CS *also* CS1 and CS2	O-chlorobenzylidene malononitrile $C_{10}H_5ClN_2$ CAS# 2698-41-1	Not Available
Vomiting Agents		
Diphenylchloroarsine/DA	Diphenylchloroarsine $C_{12}H_{10}AsCl$ CAS# 712-48-1	Not Available
Adamsite/DM	Diphenylaminechloroarsine $C_{12}H_9AsClN$ CAS# 578-94-9	Not Available
Diphenylcyanoarsine/DC	Diphenylcyanoarsine $C_{13}H_{10}AsN$ CAS# 23525-22-6	Not Available

*The U.S. CWC implementing legislation exempts these chemicals (which appear in schedule 3 of the CWC Chemical Annex) from reporting requirements if found in concentrations of less than 80 percent.

Sources:
U.S. Army Field Manual FM 3-9 and the 1956 version of TM 3-215.
Agency for Toxic Substances and Disease Registry (ATSDR). *Medical Management Guidelines (MMGs) for Blister Agents*.
Mitretek Systems. Toxicological Properties of Vesicants; Toxicological Properties of Nerve Agents. Last Revised on May 15, 2003. http://www.mitretek.org/home.nsf/HomelandSecurity/ChemBioDefense.
U.S. Army Soldier and Biological Chemical Command (SBCCOM). Material Safety Data Sheet: Distilled Mustard (HD).
U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). *Detailed Facts About Blood Agent Cyanogen Cyanide (CK); Detailed Facts About Choking Agent Phosgene (CG)*. Last Revised on July 23, 1998.
U.S. National Library of Medicine, Specialized Information Services. Hazardous Substances Data Bank (HSDB).
University of Oklahoma College of Pharmacy. Arsine Fact Sheet. 2001-2002.
Deployment Health Clinical Center (DHCC). Blister Agent Fact Sheet. Last Updated on May 21, 2003.

10.4.2 Persistence of Chemical Agents

The persistence of chemical agents is determined by their rate of vaporization. Nonpersistent compounds vaporize quickly and produce high-density clouds of chemical agent that evaporate rapidly. The hazards of these non-persistent agents result from brief contact with the clouds or from inhalation of vapors. The information on the persistence in the environment of the CW agent compounds is scattered and fragmentary. With the exception of the sulfur mustards, CW agents are generally not considered highly persistent due to the action of various degradation processes such as hydrolysis, microbial degradation, oxidation, and photolysis. However, certain degradation products may themselves be highly persistent and/or toxic. Those persistent degradation products that are not highly toxic may be important as an indicator of the former use of the site.[189]

Table 10-2 features data regarding the persistence of CWM on the battlefield. The data were derived by United States Army Center for Health Promotion and Preventative Medicine (USACHPPM) from material safety data sheets. Although the language used to describe persistence of CWM relates to the battlefield, Table 10-2 may be helpful in obtaining an initial understanding of persistence of certain chemicals in the environment. There is no data from the USACHPPM document for chemicals listed in Table 10-1 that do not appear in Table 10-2.

Persistent chemical agents are liquids that vaporize slowly or viscous materials that adhere and do not spread or flow easily. The hazards posed by persistent compounds result either from contact with the liquids or from contact with or inhalation of vapors, which persist longer than the non-persistent compounds. Persistent chemicals include mustard, lewisite, blister agents, and V-class nerve agents (VX).

Table 10-2 Persistence in the Environment of CW Agents

Common Name	Persistence
Blister Agents/Vesicants	
Lewisite/L	Somewhat shorter than for HD (sulfur mustard agent); very short duration under humid conditions.
Mustard-Lewisite Mixture/HL	Depends on munitions used and the weather. Somewhat shorter than that of HD, heavily splashed liquid of which persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.
Nitrogen Mustard/HN-1	Depends on munitions used and weather; somewhat shorter duration of effectiveness for HD, heavily splashed liquid of which persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.
Nitrogen Mustard/HN-2	Depends on munitions used and weather; somewhat shorter duration of effectiveness for HD, heavily splashed liquid of which persists 1 to 2 days under average weather conditions, and a week or more under very cold conditions.
Nitrogen Mustard/HN-3	Considerably longer than HD. HN-3 use is emphasized for terrain denial. It can be approximately 2x or 3x the persistence of HD and adheres well to equipment and personnel, especially in cold weather.
Sulfur Mustard Agent/H, HD or HS	Depends on munition used and weather; heavily splashed liquid persists 1 to 2 days in concentration to provide casualties of military significance under average weather conditions, and a week to months under very cold conditions.

[189] Munro, Nancy B. et al., "The Sources, Fate and Toxicity of Chemical Warfare Agent Degradation Products," Environmental Health Perspectives, Vol 107, Number 12, 1999.

Table 10-2 Persistence in the Environment of CW Agents (continued)

Common Name	Persistence
Mustard-T Mixture/Sulfur Mustard Agent/HT	Depends on munitions used and the weather; heavily splashed liquid persists 1 to 2 days in concentration to provide casualties of military significance under average weather conditions, and a week to months under very cold conditions.
Blood Agents	
Hydrogen Cyanide/Prussic Acid/AC	Short; the agent is highly volatile, and in the gaseous state it dissipates quickly in the air.
Cyanogen Chloride/CK	Short; vapor may persist in the jungle for some time under suitable weather conditions.
Arsine/SA	No information from source document
Choking Agents	
Phosgene/CG	Short; however, vapor may persist for some time in low places under calm of light winds and stable atmospheric conditions (inversion).
Diphosgene/DP	No information from source document
Nerve Agents	
Tabun/GA	The persistency will depend upon munitions used and the weather. Heavily splashed liquid persists 1 to 2 days under average weather conditions.
Sarin/GB	Evaporates at approximately the same rate as water; depends upon munitions used and the weather.
Soman/GD	Depends upon the munitions used and the weather. Heavily splashed liquid persists 1 to 2 days under average weather conditions.
V-Agent/VX	Depends upon munitions used and the weather. Heavily splashed liquid persists for long periods of time under average weather conditions.
Incapacitating Agents	
Agent BZ	No information from source document
Lacrimators/Tear Gases	
Chloroacetophenone/CN	Short because the compounds are disseminated as an aerosol.
Chloropicrin/PS	Short.
Chloroacetophenone and chloropicrin in chloroform/CNS	Short.
Chloroacetophenone in benzene and carbon tetrachloride/CNB	Short.
Bromobenzylcyanide/CA	Depends on munitions used and the weather; heavily splashed liquid persists one or two days under average weather conditions.
Vomiting Agents	
Adamsite/DM	Short, because compounds are disseminated as an aerosol. Soil - persistent. Surface (wood, metal, masonry, rubber, paint) - persistent. Water - persistent; when material is covered with water, an insoluble film forms which prevents further hydrolysis.

Source:

U.S. Army Center for Health Promotion and Preventative Medicine (UCACHPPM). Detailed and General Facts About Chemical Agents, TG 218.

10.4.3 Acute Toxicity of Persistent Chemical Agents

Acute toxicity values are useful in understanding the risk associated with exposure to chemical agents. *Acute toxicity* is defined as toxicity that results from short-term exposure to a toxicant. The acute toxicity of a chemical is commonly quantified as the LD50 (lethal dose that kills 50 percent of the exposed population) or LCt50 (lethal concentration that kills 50 percent of the exposed population in a specified period of time). These values provide statistically sound and reproducible measures of the relative acute toxicity of chemicals.

Table 10-3 shows acute human toxicity data (LD50 and LCt50) for oral, dermal, and inhalational routes of exposure for the chemical warfare agents listed in Table 10-1. In cases when human toxicity data were not available, data on exposure of laboratory animals (e.g., rats) to the agent(s) were substituted. Caution should be used in extrapolating this data to humans.

Table 10-3. Acute Human Toxicity Data for Chemical Warfare Agents

Chemical Agent	LD50	LCt50
Blister Agents/Vesicants		
Lewisite/L	50 mg/kg (oral, rat)	100,000 mg-min/m^3 (dermal, human)
	24 mg/kg (dermal, rat)	1,200 to 2,500* mg-min/m^3 (inhalation, human)
Mustard-Lewisite Mixture/HL	Not Available	about 10,000 mg-min/m^3 (dermal, human)
		about 1,500 mg-min/m^3 (inhalation, human)
Nitrogen Mustard/HN-1	2.5 mg/kg (oral, rat)	20,000 mg-min/m^3 (dermal, human)
	17 mg/kg (dermal, rat)	1,500 mg-min/m^3 (inhalation, human)
Nitrogen Mustard/HN-2	10 mg/kg (oral, rat)	3,000 mg-min/m^3 (inhalation, human)
	12 mg/kg (dermal, rat)	
Nitrogen Mustard/HN-3	5 mg/kg (oral, rat)	10,000 mg-min/m^3 (dermal, human)
	2 mg/kg (dermal, rat)	1,500 mg-min/m^3 (inhalation, human)
Sulfur Mustard Agent/H, HD or HS	0.7 mg/kg (oral, human)	5,000 to 10,000* mg-min/m^3 (dermal, human)
	20 to 100* mg/kg (dermal, human)	900 to 1,500* mg-min/m^3 (inhalation, human)
Mustard-T Mixture/Sulfur Mustard Agent / HT	Not Available	
Phenyldichloroarsine / PD	16 mg/kg (dermal, rat)	2,600 mg-min/m^3 (inhalation, human)

Table 10-3. Acute Human Toxicity Data for Chemical Warfare Agents

Chemical Agent	LD50	LCt50
Ethyldichloroarsine/ED	Not Available	1,555 mg/m^3 for 10 min (inhalation, mouse)
Methyldichloroarsine/ MD	Not Available	
Phosgene Oxime/CX	Not Available	3,200 mg-min/m^3 (estimated)(human)
Blood Agents		
Hydrogen Cyanide/ Prussic Acid/AC	100 mg/kg (dermal, human)	2,000 mg/m^3 for 0.5 min (inhalation, human)
		20,600 mg/m^3 for 30 min (inhalation, human)
Cyanogen Chloride/CK	6 mg/kg (oral, cat)	11,000 mg-min/m^3 (human)
Arsine/SA	Not Available	390 mg/m^3 for 10 min (inhalation, rat)
Choking Agents		
Phosgene/CG	Not Available	3,200 mg/m^3 (inhalation, human)
Diphosgene/DP	Not Available	
Nerve Agents		
Tabun/GA	3.7 mg/kg (oral, rat)	135 mg/m^3 for 0.5-2.0 min at RMV of 15 L/min (inhalation, human)
	14 to 15 mg/kg (dermal, human)	200 mg/m^3 for 0.5-2.0 min at RMV of 10 L/min (inhalation, human)
Sarin/GB	0.55 mg/kg (oral, rat)	70 mg-min/m^3 at 15 L/min (inhalation, human)
	24 mg/kg (dermal, human)	
Soman/GD	5 mg/kg (dermal, human)	70 mg-min/m^3 at 15 L/min (inhalation, human)
V-Agent/VX	0.142 mg/kg (dermal, human)	30 mg-min/m^3 at 15 L/min (inhalation, human)
Incapacitating Agents		
Agent BZ	Not Available	200,000 mg-min/m^3 (estimated)(human)
Lacrimators/Tear Gases		
Chloroacetophenone/CN	50 to 1,820* mg/kg (oral, rat)	7,000 mg-min/m^3 from solvent (human)
		14,000 mg-min/m^3 from grenade (human)
Chloropicrin/PS	250 mg/kg (oral, rat)	2,000 mg-min/m^3 (human)

Table 10-3. Acute Human Toxicity Data for Chemical Warfare Agents

Chemical Agent	LD50	LCt50
Chloroacetophenone & Chloropicrin in Chloroform/CNS	Not Available	11,400 mg-min/m^3 (human)
Chloroacetophenone in Benzene & Carbon tetrachloride/CNB	Not Available	11,000 mg-min/m^3 (human)
Bromobenzylcyanide	Not Available	8,000 mg-min/m^3 (estimated)(human)
O-Chlorobenzylidene/CS also CS1and CS2	178 mg/kg (oral, rat)	61,000 mg-min/m^3 (human)
Vomiting Agents		
Diphenylchloroarsine	Not Available	
Adamsite/DM	Not Available	variable, average 11,000 mg-min/m^3 (human)
Diphenylcyanoarsine	Not Available	

*value varies depending on source.

Notes:

In cases where data on human exposure were not available, data on exposure of laboratory rats to the agent(s) were substituted. Caution should be used in extrapolating this data to humans.

RMV – respiratory minute volume

LD50 – dose which kills 50% of the exposed population; typically expressed in units of mg/kg body weight

LCt50 – concentration which kills 50% of the exposed population in a specified period of time; typically expressed as product of the chemical's concentration in air (mg/m3) and the duration of exposure (min)

Dermal – absorption through the skin

Oral – intake via mouth

Inhalation – intake via the lungs

Sources:

Mitretek Systems. *Toxicological Properties of Vesicants; Toxicological Properties of Nerve Agents*. Last Revised on May 15, 2003. http://www.mitretek.org/home.nsf/HomelandSecurity/ChemBioDefense

U.S. Army Soldier and Biological Chemical Command (SBCCOM). Material Safety Data Sheet: Distilled Mustard (HD); Lethal Nerve Agent (GD); Lethal Nerve Agent (GB).

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). *Detailed Facts About Blood Agent Cyanogen Cyanide (CK), Hydrogen Cyanide (AC); Blister Agent Phosgene Oxime (CX), Mustard-Lewisite Mixture (HL), Nitrogen Mustard (HN-1), (HN-2), (HN-3), Lewisite (L), Sulfur* ***Mustard Agents H and HD; Nerve Agent VX, Nerve Agent GA; Psychedelic Agent 3-Quinuclidinyl Benzilate (BZ); Tear*** *Agent 2-Chloroacetophenone (CN), Chloropicrin (PS), Chloroacetophenone and Chloropicrin in Chloroform (CNS), Chloroacetophenone in Benzene and Carbon Tetrachloride (CNB), a-Bromobenzylcyanide (CA), o-Chlorobenzylidene Malonitrile (CS); Vomiting Agent Adamsite (DM)*. Last Revised on July 23, 1998.

U.S. Army Chemical Biological Defense Command Edgewood. Material Safety Data Sheet: Lewisite.

National Toxicology Program (NTP). NTP Chemical Repository. Last revised on June 3, 2003.

U.S. Department of Labor. Occupational Safety & Health Administration. Occupational Safety and Health Guidelines. The Regisry of Toxic Effects of Chemical Substances (RTECS).

U.S. National Library of Medicine, Specialized Information Services. Hazardous Substances Data Bank (HSDB).

10.4.4 Degradation Products of Chemical Munitions and Agents

Many chemical agents are broken down by weathering processes into both hazardous and nonhazardous materials. The weathering effects of sun, rain, and wind will dissipate, evaporate, or decompose chemical agents. Specifically, sunlight causes catalytic decomposition and evaporation, rain or dew causes hydrolysis, and wind accelerates the natural process of evaporation.

When addressing the hazards of CWM at a site, special attention should be paid to the decomposition products that often pose risks to human health and the environment as a result of their toxicity and persistence. While a number of degradation products exist, only a few of them are persistent and highly toxic.[190]

The following text describes examples of some common chemical agent decomposition products of CWM and an overview of their persistence in the environment and toxicity. The environmental conditions and the length of time that an agent has been exposed to the environment will determine the extent of the degradation and whether some or all of the degradation products and subsequent daughter products (described in the following sections) will be present. Table 10-4 provides more detail on toxicity of these degradation products.

- **Sarin (GB)** – reacts with water (hydrolyzes) under acidic conditions to form hydrofluoric acid, isopropyl methylphosphonic acid (IMPA), which slowly hydrolyzes to methylphonic acid (MPA). IMPA, although environmentally persistent has been shown to present low acute oral toxicity to rats and mice. MPA is essentially nontoxic to mammalian and aquatic organisms.[8] Hydrofluoric acid is an extremely corrosive material that must be handled with extreme caution unless copiously diluted. Sarin will hydrolyze under alkaline (basic) conditions to form sodium (or other metallic) isomethyl phosphonate salt.

- **Tabun (GA)** – produces a variety of hydrolysis products under acidic, basic, and neutral conditions, including hydrogen cyanide, ethylphosphoryl cyanidate, organic acids and esters, ethyl alcohol, dimethylamine, ethyl N,N-dimethylamido phosphoric acid and phosphoric acid.

- **VX** – forms a variety of degradation products. The most persistent products in weathered soil samples are bis(2-diisopropylaminoethyl)disulfide (EA 4196) and MPA. The most toxic is S-(2-diisopropylaminoethyl) methylphosphonothioic acid (EA 2192). The intermediate VX hydrolysis product EA 2192 may be stable in water but is degraded rapidly in soil. It is nearly as toxic as VX. EMPA and MPA are final degradation products that exhibit relatively low toxicity to mammalian species.Other less toxic degradation products include phosphorus-containing organic acids, sulfur-containing compounds, organic phosphorus-containing esters, and ethyl alcohol.[8]

- **Soman (GD)** – hydrolyzes to form primarily pinacolyl methylphosphonic acid, which has

[190] Munro, N.B. et al., *The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products,* Environmental Health Perspectives, Vol. 107, No. 12, December 1999.

a similar structure to IMPA. IMPA has even been shown to exhibit low mammalian toxicity. GD also slowly hydrolyzes to MPA.[8]

- **Mustard (HD)** – hydrolyzes to form hydrochloric acid (a strong mineral acid), thiodiglycol (TDG) and 1,4-oxathiane. The most persistent degradation product is TDG but it is suseptible to microbial degradation and has been demonstrated to be low toxicity to mammalic and aquatic species. At burial sites, a commonly found breakdown product is 1,4-dithiane.

- **Lewisite** – hydrolyzes under acidic conditions to form hydrochloric acid and the nonvolatile (solid) compound chlorovinylarsenious oxide (lewisite oxide). Although this compound is a much weaker blistering agent than Lewisite it is still highly toxic and has vesicant properties. Hydrolysis in basic conditions, such as decontamination with alcoholic caustic or carbonate solution, produces acetylene, a very flammable gas, and trisodium arsenate. Therefore, the decontamination solution would contain a toxic form of arsenic.[191]

Table 10-4 summarizes chemical agent degradation products that are known to have significant environmental persistence and toxicity. *Environmental persistence* refers to chemicals that resist degradative processes and remain in the environment for very long periods of time. Significant persistence refers to compounds that are stable in the environment for months to years.

Table 10-4. Summary of Known Persistent or Toxic Chemical Agent Degradation Products

Chemical Agent	Degradation Process	Degradation Products	Persistence	Relevant Routes of Exposure	Toxicity, LD50 (mg/kg)
Sulfur mustard (HD)	Hydrolysis	Thiodiglycol $C_4H_{10}O_2S$ CAS# 111-48-8 Dithiane $C_4H_8S_2$ CAS# 505-23-7	Moderate	Oral	Rat oral: 6,610 guinea pig oral: 3,960
Lewisite (L)	Hydrolysis, dehydration	2-Chlorovinyl arsenous oxide (Lewisite oxide) C_2H_2AsClO CAS# 3088-37-7 Arsenic AS CAS# 7440-38-2	High	Dermal	Unknown
V-Agent (VX) O-ethyl-S-[2-diisopro-pylaminoethyl]methyl-phosphonothionate	Hydrolysis	S-(Diisopropylaminoethyl) methyl phosphonothionate (EA 2192)	Moderate	Oral	Rat oral LD50: 0.63

[191]Materiel Safety Data Sheets, Edgewood Chemical Biological Center (ECBC), Department of the Army.

Table 10-4. Summary of Known Persistent or Toxic Chemical Agent Degradation Products (continued)

Chemical Agent	Degradation Process	Degradation Products	Persistence	Relevant Routes of Exposure	Toxicity, LD50 (mg/kg)
		Ethyl methylphosphonic acid (EMPA) C3H9O3P CAS# 1832-53-7	Moderate	Oral	No data
	Formed from EMPA	Methylphosphonic acid (MPA) CH_5O_3P CAS# 993-13-5	High	Oral	Rat oral LD50: 5,000
Sarin (GB) Isopropyl methyl-phosphonofluoridate	Hydrolysis	Isopropyl methylphosphonic acid (IMPA) $C_4H_{11}O_3P$ CAS#1832-54-8	High	Oral	Rat oral LD50: 6,070
		Methylphosphonic acid (MPA) CH_5O_3P CAS# 993-13-5	High	Oral	Rat oral LD50: 5,000
	Impurity	Diisopropyl methylphosphonate (DIMP) C7H17PO3 CAS# 1445-75-6	High	Oral	Rat oral LD50: 826
Soman (GD) Ethyl N,N-dimethyl-phosphoroamido-cyanidate	Hydrolysis	Methylphosphonic acid (MPA) CH_5O_3P CAS# 993-13-5	High	Oral	Rat oral LD50: 5,000

Source:
Munro, N.B.et. Al., The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products, *Environmental Health Perspectives,* Vol, 107. No.12, December 1999.

10.5 Detection of CWM

Techniques for locating buried chemical munitions and containers are the same as those for the detection of conventional munitions. The appropriate geophysical detection technology should be selected based on the container's material (e.g., steel vs. glass). Chapter 4 described the variables associated with the selection of geophysical detection technologies. Once the presence of CWM or chemical agent(s) are suspected, they must be identified. Several methods for detecting and identifying chemical agents exist. Some of the more common methods are discussed in Table 10-5. Each detection method has strengths and weaknesses that will need to be weighed against the conditions and the chemicals suspected at individual sites.[192]

[192]The term detection is used in two ways in this section. The first discussion refers to locating discrete metallic items through geophysical investigation. The second use refers to finding and identifying the chemical agent itself. The detection tools for locating discrete metallic items are discussed in Chapter 4.

Table 10-5. Common Methods for Monitoring for and Sensing Chemical Agents

Detection Types	Description	Advantages and Disadvantages
Chemical Agent Monitor (CAM™)	Used as a monitor for chemical agents. Area reconnaissance is accomplished by moving the CAM through the area of concern. The CAM is usually used in conjunction with other detection methods. The CAM can detect nerve and blister agents at moderately low levels that could affect personnel over a short time.	C Sensitivity – False alarms have been a problem with CAM, such as false alarms caused by the presence of aromatic vapors from materials such as perfumes, food flavorings, cleaning compounds, disinfectants, and smoke and fumes in exhaust from rocket motors and munitions. C Detector uses a radiation source that could be a problem when moving the detector to different States. C Operates in nerve agent or mustard mode. C Quick response time.
Individual Chemical Agent Detector (ICAD)	Uses two electrochemical sensors: one sensor is sensitive to nerve agents, blood agents, and choking agents; the second sensor detects blister agents. When preset threshold levels are reached, an alarm is activated.	C Detector can be worn on outside of clothing. C Quick response time – less than 2 minutes for GA, GB, BD, and HD. Shorter alarm times for higher concentrations and other agents.
Chemical Agent Detector Paper (ABC-M8)	Used to detect liquid chemical agents. The paper turns different colors according to the type of agent to which it is exposed. V-type nerve agents turn it green, G-type nerve agents turn it yellow, blister agents turn it red.	C Paper must be examined in white light (which could be a problem in night operations). C Detection thresholds are high. C Subject to false alarms from other chemicals and from rubbing the paper on surface instead of blotting. C Easy to use, minimal training required.
Chemical Agent Detector Paper (M9)	M9 is the most widely used detector for liquid chemical agents and is more sensitive and reacts more rapidly than ABC-M8 paper. M9 paper reacts to chemical agents by turning a red or reddish brown color. Detection of a chemical agent by the M9 paper should be confirmed with the M256 kit.	C High detection thresholds. C Subject to false alarms from exposure to petroleum products. C Easy to use, minimal training required.

Table 10-5. Common Methods for Monitoring for and Sensing Chemical Agents (continued)

Detection Types	Description	Advantages and Disadvantages
M256 Chemical Agent Detector Kit	Can detect chemical agent in liquid or vapor forms. The M256 kit is usually used to confirm chemical agent presence after an alarm and to identify the type of agent present. It is not used to monitor for the presence of a chemical agent. Kit contains vials of liquid reagents that are combined and exposed in a specific sequence to indicate presence of chemical agent vapors. Use of the kit entails manual manipulation of the kit contents.	C Proceeding through the full series of tests requires 20-25 minutes. C Step-by-step instructions are provided with each kit to avoid misuse and consequent misinterpretation.
M272 Water Testing Kit	Used to detect chemical agents in raw or treated water. Detects mustard agent (HD), cyanide (AC), Lewisite (L), and nerve agents (G and V series).	C Capable of detecting agents at levels safe for human use. C Portable.
MINICAD	Hand-held chemical agent detector kit that simultaneously detects trace levels of nerve and blister agents.	C No false alarms resulting from other chemical vapors. C Provides a data record. C Small, easy to carry – weighs only 1 pound.
APD 2000 (Sabre)	Hand-held detector of GA, GB, GD, VX, HD, HN, Lewisite, pepper spray, and mace.	C Superior interference resistance. C Has a data logger option. C Small, easy to carry – weighs 6 pounds.
Portable GC/MS	Gas chromatograph/mass spectrometer	C Detects and quantifies most chemicals. C Sampling and analysis time is longer than for instruments designed as detectors. C Requires a technician operator. C Analyzes industrial chemicals as well as chemical agents.

Table 10-5. Common Methods for Monitoring for and Sensing Chemical Agents (continued)

Detection Types	Description	Advantages and Disadvantages
MINICAMS (Miniature Chemical Agent Monitoring System)	Portable monitoring unit available with flame ionization detector (FID) or flame-photometric detector (FPD). Provides near real time information. Various versions of MINICAMS can detect some chemical agents and other air pollutants depending on the detector and the sampling module that is installed. Sampling module may be a plug-in flow-through module, loop-sampling plug-in module, or sorbent sampling plug-in module. MINICAMS7 includes a gas chromatograph, which the manufacturer claims can detect chemical agent vapors in air to meet the Surgeon General's 8-hour TWA standard.	C Portability of unit that can be used to monitor areas or specific point. C Programmable to sequentially sample from a number of sample points.
JCAD	Hand-held detector that uses an advanced surface acoustic wave (SAW) technology. Capable of detecting the presence of nerve agents (G and V series), blister agents (HD, HN3, L), blood agents (AC, CK), and toxic industrial chemicals.	C Compact size provides real advantage for portability and use in the field. C Has multiagent detection capability. C Can be mounted in a fixed location and linked to RS 232 communications port for feedback from remote locations.
SAW MINICAD mk II	Lightweight, solid-state detector, using surface acoustical wave sensor technology. Capable of simultaneous detection of trace levels of nerve and blister agents.	C Sensor is selective to the chemical agents and does not give false alarms due to other chemical vapors. C Unit is battery operated, can store data from detection sensor, is fully automatic, and is lightweight.
Portable Isotopic Neutron Spectrometer (PINS)	Nondestructive chemical assay tool that can identify previously cataloged contents of munitions and chemical- storage containers use of special fingerprinting algorithms.	C Portable C Easy to use C Rugged enough for military or civil defense use C Assay times: 100 to 1,000 seconds

Table 10-5. Common Methods for Monitoring for and Sensing Chemical Agents (continued)

Detection Types	Description	Advantages and Disadvantages
Digital Radiography/ Computed Tomography (DRCT)	Creates high-clarity X-rays of a munition's interior. The DRCT system is used when information on the contents, configuration, or condition of the munition is conflicting or unknown.	C X-rays are so clear that analysts can often determine the condition of the bomb's firing mechanisms and whether it has been damaged from years of storage or burial.
Mobile Munitions Assessment Systems (MMAS)	Includes equipment for nonintrusively identifying munitions and for assessing the condition and stability of fuzes, firing trains, and other potential safety hazards. The Phase II MMAS is currently being tested and qualified for use by the INEEL and the Army. The Phase II system contains several new assessment systems that significantly enhance the ability to assess CWM.	C The system provides a self-contained, integrated command post, including an on-board computer system, communications equipment, video and photographic equipment, weather monitoring equipment, and miscellaneous safety-related equipment.

Market Survey and Literature Search of Monitoring Technologies; July 22, 1996; U.S. Army Program Manager for Chemical Demilitarization
Site Monitoring Concept Study; September 15, 1993; U.S. Army Chemical Destruction Agency
U.S. Army Field Manual (FM) 3-4 NBC Protection
Department of the Army (DA) Pamphlet 385-61 Toxic Chemical Agent Safety Standards
U.S. Army Technical Manual (TM) 43-0001-26-1 Army Equipment Data Sheets: Chemical Defense Equipment
U.S. Army Technical Manual (TM) 3-6665-225-12 Operator's and Organizational Maintenance Manual: Alarm, Chemical Agent, Automatic: Portable, Manpack M8
U.S. Army Technical Manual (TM) 3-6665-254-12 Operator's and Organizational Maintenance Manual: Detector Kit, Chemical Agent, ABC-M18A2
U.S. Army Technical Manual (TM) 3-6665-307-10 Operator's Manual for Detector Kit, Chemical Agent, M256 and M256A1
U.S. Army Technical Manual (TM) 3-6665-311-10 Operator's Manual for Paper, Chemical Agent Detector: M9
U.S. Army Technical Manual (TM) 3-6665-312-12andP Operator's and Organization Maintenance Manual for the M8A1 Automatic Chemical Agent Alarm

The most effective tool for determining the presence of CWM inside a suspected chemical munition or container is the Portable Isotopic Neutron Spectrometer (PINS). The PINS beams neutrons into an enclosed container, yielding a spectrum that is collected and stored. The PINS Analysis software analyzes the spectrum and determines the contents of the container. Another useful instrument is the Digital Radiography/Computed Tomography (DRCT) unit. A DRCT can effectively produce a CAT scan of a munition or container. Both of these tools have been placed on mobile platforms called Mobile Munitions Assessment Systems (MMAS) for identifying suspected chemical weapons materials. The MMAS units are available from the U.S. Army Technical Escort Unit, Aberdeen Proving Ground, Maryland.

In addition, the Army uses more sophisticated air-monitoring equipment on its mobile treatment systems that achieves near real time monitoring results. An example of this equipment is the Miniature Chemical Agent Monitoring System (MINICAMS), which is a device capable of monitoring for blister, nerve, and some other agents to well below their required acceptable exposure limits (AELs). Devices such as MINICAMS are typically used in areas where excavations are ongoing or where mobile destruction equipment is being operated.

10.5.1 Laboratory Analysis of CWM

When environmental samples from sites contaminated with CWM are sent to laboratories for analysis, those samples may pose a threat to the laboratories that analyze them. For this reason, only a few commercial laboratories are authorized for the analysis of CWM. All environmental samples must be sent to approved laboratories.

10.6 Response, Treatment, and Decontamination of Chemical Agents and Residues of CWM

Because of the dual hazards of explosive capability and potential lethality, CWM poses significant response, treatment, remediation and decontamination challenges. This section addresses these components.

> **Decontamination**
>
> Decontamination is the process by which any person, object, or area is made safe through the absorption, destruction, neutralization, rendering harmless, or removal of chemical or biological material, or the removal of radioactive material clinging to or around the materials.

10.6.1 Response

Because of both the explosive and the chemical hazards, Army guidance specifies a hierarchy for conducting response actions at sites containing CWM alone or both CWM and conventional munitions. This hierarchy calls for explosive hazards to be addressed and mitigated first, followed by non-stockpile CWM hazards.[193]

At any site where chemical contamination is known or suspected, the Army Technical Escort Unit (TEU), a division of the U.S. Army Soldier and Biological Chemical Command (SBCCOM), must be called in to assess the CWM and determine how it can be handled. One of the ways in which CWM is handled is destruction.

Procedures for the destruction of chemical weapons under controlled conditions are spelled out in detailed, case-by-case plans developed by the Army and submitted to State regulatory officials. The destruction of chemical weapons frequently involves the use of mobile equipment tested by the Army and permitted by each State for exactly that purpose.

[193] Interim Guidance for Biological Warfare Materiel (BWM) and Non-Stockpile Chemical Warfare Materiel (CWM) Response Activities, Department of the Army, 13 April 1998.

10.6.2 Treatment

In 2003, the National Research Council, Board of Army Science and Technology, published the results of their review of ***Systems and Technologies for the Treatment of Non-Stockpile Chemical Warfare Material.*** They concluded that the Army has or will shortly have a number of options for the destruction and/or treatment of chemical agent, including the use of fixed facilities and mobile systems that can use one or a number of combinations of individual treatment technologies. Like mobile systems, individual treatment technologies may be incorporated into a larger entity such as a fixed facility or mobile systems that are transported to the site of a find.

Table 10-6 represents an overview of facilities, mobile treatment systems, and individual treatment technologies that were reviewed by the National Research Council committee. Because of the safety concerns associated with movement of CWM, Army guidance (based on 50 U.S.C. 1512-1521) expresses a preference for on-site treatment of CWM. However, if on-site treatment is not an option, such as at a heavily populated FUDS, the Army preference is for on-site storage or storage at the nearest military facility within the State until the CWM or agent-contaminated material can be treated. Out-of-State storage is the Army's least preferred option. The committee presented what their recommendations were from the review regarding the uses of these treatment options.[194]

The treatment options identified in Table 10-6 are not all currently in use for NSCWM. For example, the table lists treatment options for non-stockpile items that the Army has historically used to effectively destroy stockpiled items. However, all were reviewed for their potential use as recent legislation specifically allowed the use of stockpile facilities to destroy non-stockpile CWM. A few of the key recommendations of the NRC are summarized below:

- Treatment facilities developed for the stockpile program may be very appropriate for treatment of NSCWM, if regulatory agencies and other stakeholders can support this.
- The Rapid Response System for the destruction of CAIS PIGS and large numbers of loose CAIS vials and bottles is an expensive but adequate treatment for these items.
- The Explosive Destruction System (EDS) developed as a transportable system for the destruction of chemical munitions in the field has performed well for its intended uses and should be further developed for additional uses. However, given the amount of potential NSCWM that may be buried in various sites around the country, it may not have sufficient throughput to be efficient in the future.
- The development and testing of the tent and foam system for controlling on-site detonation of unstable munitions should continue to be explored as an alternative to open detonation.
- The Donovan Blast Chamber (developed for conventional munitions) is currently being tested for CWM in Belgian. "If results are encouraging and it appears that the DBC can

[194]Ibid. Systems and Technologies for the Treatment of Non-stockpile Chemical Warfare Materiel, Board on Army Science and Technology, National Research Council, National Academy Press, 2002.

be permitted in the United States, it should be considered for use at sites where prompt disposal of large numbers of munitions is required."[195]

The table is organized into three categories: facilities, mobile treatment systems, and individual treatment technologies. The following sections provide a review of these categories.

Table 10-6. Potential Treatment Facilities for NSCWM

Treatment Option	Description
Facilities	
Non-stockpile facilities Pine Bluff Non-Stockpile Facility (PBNSF) (in final design)	Designed to use chemical neutralization and associated technologies to address the recovered non-stockpile items stored at Pine Bluff Arsenal, Arkansas.
Munitions Assessment and Processing System (MAPS) (under construction)	Designed to use chemical neutralization and associated technologies to address the recovered non-stockpile items found at Aberdeen Proving Ground, Maryland.
Use of stockpile destruction facilities for disposal of non-stockpile materiel	Equipped to open stockpile chemical munitions, drain and incinerate agent, and destroy energetics.
Research and development facilities Chemical Transfer Facility (CTF)	Research facility at Aberdeen Proving Ground, Maryland, capable of destroying stockpile and non-stockpile agents.
Chemical Agent Munitions Disposal System (CAMDS)	Research facility at Tooele, Utah, capable of destroying non-stockpile munitions that contain agent fills not easily accommodated at other facilities (eg., lewisite).
Treatment, storage, and disposal facilities	Capable of high-temperature incineration of secondary waste streams produced by the RRS, EDS, and other systems.

[195]Ibid.

Table 10-6. Potential Treatment Facilities for NSCWM (continued)

Treatment Option	Description
Mobile Treatment Systems	**Facilities**
Rapid Response System (RRS)	Non-stockpile facilities Pine Bluff Non-Stockpile Facility (PBNSF) (in final design)
Single CAIS Accessing and Neutralization System (SCANS) (in design)	Munitions Assessment and Processing System (MAPS) (under construction)
Explosive Destruction System (EDS)	Use of stockpile destruction facilities for disposal of non-stockpile materiel
Donovan Blast Chamber (DBC) (in testing for use with CWM)	Research and development facilities Chemical Transfer Facility (CTF)
	Chemical Agent Munitions Disposal System (CAMDS)
	Treatment, storage, and disposal facilities
Individual Treatment Technologies	
Plasma arc	High-temperature technology for direct destruction of agent or for destruction of secondary waste streams produced by the RRS, EDS, and other systems.
Chemical oxidation	Low-temperature technology potentially applicable to destruction of liquid secondary waste streams produced by the RRS, EDS, and other systems.
Wet air oxidation	Moderate-temperature technology potentially applicable to the destruction of liquid secondary waste streams produced by the RRS, EDS, and other systems.
Batch supercritical water oxidation (SCWO)	High-temperature technology potentially applicable to the destruction of liquid secondary waste streams produced by the RRS, EDS, and other systems.
Neutralization (chemcial hydrolysis)	Low-temperature technology for hydrolysis of neat chemical agents and binary precursors.
Open burning/open detonation (OB/OD)	Historic blow-in-place method for destroying dangerous munitions.
Tent and foam	Partially contained blow-in-place method for destroying dangerous munitions.

10.6.2.1 *Non-stockpile Facilities*

Non-stockpile facilities are designed to destroy large quantity of dissimilar CWM and stockpile facilities are constructed to destroy large quantities of similar CWM.

The Munitions Assessment and Processing System (MAPs) mentioned in the table as a fixed facility was under construction during the National Research Council's (NRC) review. It was designed to handle explosively configured chemical munitions and smoke rounds to be recovered during the Installation Restoration Program at APG.

The Pine Bluff non-stockpile facility is designed to process RCWM binary chemical weapons components CAIS and chemical samples at PBA.

10.6.2.2 *Research and Development Facilities*

The Army has two R&D facilities in the United States; the Chemical Transfer Facility (CTF) at Aberdeen Proving Ground (APG) and the Chemical Agent Munitions Disposal System (CAMDS) at Desert Chemical Depot to destroy items containing Lewisite. The CT facility handles CWM recovered from APG.

10.6.2.3 *Treatment, Storage, and Disposal Facilities*

A fourth type of fixed facility (treatment, storage, and disposal facilities, or TSDFs) differs from the rest in that commercial TSDFs cannot be used to treat CWM. They can accept secondary waste generated by either mobile systems or individual treatment technologies if the waste no longer contains agent (except at de minimis levels).

10.6.2.4 *Mobile Treatment Facilities*

Table 10-5 lists four mobile treatment systems. The Explosive Destruction System (EDS) and the Rapid Response System (RRS) are the primary systems used. The EDS is designed to treat munitions that contain chemical agents with energetics equivalent to 3 pounds of TNT. These are considered too unstable to be transported and stored. The RRS is designed to treat recovered CAIS, which contain small amounts of various industrial SCANS (Single CAIS Accessing and Neutralization System) is under development to treat individual CAIS vials or bottles. The Donovan Blast Chamber (DBC), originally designed to treat conventional explosive munitions, was modified to treat explosively configured CWM and offers a higher rate of throughput than the EDS. It is not yet approved for use with CWM, by DDESB, but its' use is under evaluation.

10.6.2.5 *Individual Treatment Facilities*

The treatment facilities and systems discussed involve a combination of technologies, including the preparation of the agent for processing, agent accessing, agent destruction, and treatment of secondary waste materials. There are individual treatment technologies that can be used on their own or integrated into the systems and facilities to accomplish specific tasks. These technologies such as plasma arc and chemical oxidation are listed and described in table 10-6. It is important to note that at the time of the NRC's study, some of these technologies were still considered experimental and had not been demonstrated to have met EPA and state requirements. It is important to note that the use of OD in a field environment necessities ideal conditions in which the area can withstand a significant high-order detonation so that all chemical munitions are consumed and there are no personnel or property located in the downwind hazard area. The disadvantages of this method are many, including noise impacts, limit on the quantity that can be destroyed at one time, and the need for regulatory and public approval. This is also the case with other technologies that may create air emissions such as incineration.

10.6.3 Technical Aspects of CWM Remediation Decontamination

At sites where deterioration of CWM has occurred as a result of weathering (see 10.4.3), the breakdown products are often remediated using techniques for hazardous chemical soil remediation. Occasionally, until the TEU can make arrangements for decontaminating the chemical agents, they will construct either a cap made of soil or foam to restrict the absorption and volatilization of chemical agents. However, after some time, such temporary caps will allow vapors to seep through. These temporary sealing techniques protect potential receptors until a more permanent remedy can be conducted.

Chemical Decontamination

In February 2001, at the Rocky Mountain Arsenal, Army experts completed the destruction of eight Sarin bomblets using an explosive destruction system. This transportable explosives destruction system was designed to dispose of CWM in a safe and environmentally sound manner. The device functions by first detonating the chemical munitions to expose the chemical agent filler in the containment vessel. Next, reagents are pumped into the vessel to react with the chemical agent filling. The resulting compound is then drained into drums for shipment to a hazardous waste treatment facility, and the air from the device is vented through a carbon filter to remove all chemical agents from the

As a result of CWM response, there is a need to remediate any residual chemical agent that may be on equipment or PPE. All procedures for the emergency field decontamination of chemical agents must follow standard operating procedures (SOPs) based on Army Field Manual 3-7.[196] These are techniques (especially physical removal) that are typically employed in a field environment. Two commonly used decontamination methods are described below:

- **Physical removal** – washing or flushing of the surface with water, steam, or solvents. Soap and boiling water or steam are often practical and effective methods for decontaminating smaller objects such as personal protective equipment (PPE) and equipment. Water will hydrolyze most chemical agents, but large quantities of water and sufficient pressure are required to make this method practical. During any decontamination operation, appropriate personal protective equipment (PPE) must be used to ensure safety of the workers, and all downwind hazards must be analyzed and minimized in order to reduce exposure to the surrounding community and environment. All water and waste water that are generated from the decontamination operation must be properly handled and disposed of in accordance with appropriate

[196] NBC Field Handbook, Department of the Army Field Manual, FM 3-7, September 1994.

regulations. This is explained in more detail in the following section.

- **Chemical neutralization** – triggers a chemical reaction between the chemical agent and the decontaminant, usually resulting in the formation of a new compound that may be remediated using a RCRA-permitted incinerator. Generally, a chlorinated bleach, such as supertropical bleach, chlorinated lime, bleaching powder, or chloride of lime, is used for this purpose. Except under emergency situations, chemical neutralization is conducted only in contained areas.

10.7 Safety Considerations at Sites Containing Chemical Agents

10.7.1 DoD Chemical Safety Requirements in the DoD Ammunition and Explosives Safety Standards

The DoD Ammunition and Explosives Safety Standards (DoD 6055.9-STD, July 1999) contain strict safety requirements for properties currently or formerly owned by DoD that are contaminated with CWM and require that all means possible be used to protect the public. Chapter 11 of the DoD Explosives Safety Standard specifically addresses safety standards for chemical agents while acknowledging the explosive hazards accompanying CWM. Chapter 11 does not apply in emergency situations when disposal or decontamination needs are immediate and when delay will increase the risk to human life or health.

In the event that an item is discovered that is suspected of containing CWM, the Army, as well as each branch of military service, has specific reporting and emergency response procedures that need to be followed in order to ensure the safety of everyone in the vicinity of the possible contaminant. The first response is always to leave the area immediately, without touching or disturbing the item, and to notify the agency indicated by the branch of service that has jurisdiction over the range. The Technical Escort Unit out of Aberdeen, Maryland, responds to all reports of possible CWM.

The safety requirements for CWM at MRSs are essentially the same as those for explosives safety, with some modifications to address the unique safety considerations of chemical agents:

- Hazard Zone Determination - As required by the DoD Explosives Safety Standard, hazard zone calculations, or quantity-distance data, enable site planners to estimate damage or injury potential based on a maximum credible event (MCE). Planners consider the propagation characteristics of the ammunition, the amount of agent that could potentially be released, and the nature of the potential release (evaporation or aerosolization). For agent-filled ammunition without explosives, the MCE factors should address the number of items likely to be involved, the quantity of agent likely to be released in such an event, and the percentage of that agent that would be disseminated in an event. For combined chemical and explosive components, the MCE should be based on the detonation of the explosive components that will produce the maximum release of chemical agent.
- The DDESB must review and approve the chemical safety aspects of all plans for leasing, transferring, excessing, disposing of, or remediating DoD real property when chemical agent contamination exists or is suspected to exist.
- The DDESB must review plans to remediate FUDS at which chemical agent

contamination exists or is suspected to exist.

- Significant worker safety requirements should be followed to prevent exposure to chemical agent, including measuring AELs, controlling exposures, and using protective equipment and clothing in areas known to contain or suspected of containing CWM.
- Medical surveillance, including annual health assessments, must be provided for employees at sites where CWM is or is thought to be located.
- Personnel safety training must be provided to those who work with chemical agents and ammunition, including agent workers, firefighters, and medical and security personnel, to maintain a safe working environment.
- Labeling and posting of hazards is required to warn personnel of potential hazards at sites containing or thought to contain CWM.
- Procedures for decontaminating protective equipment and clothing in the event of spills must be outlined.
- Transportation requirements for bulk chemical agent and materials contaminated with chemical agents must be followed.

10.7.2 Chemical Safety Requirements

In addition to the DoD Explosives Safety Standards, several other guidance documents and manuals contain requirements for managing CWM at MRSs. These documents include Army Regulation 385-61, the *Army Chemical Agent Safety Program*, and Department of the Army Pamphlet 385-61, *Toxic Chemical Agent Safety Standards*. All procedures for the decontamination of chemical agents must follow SOPs based on Army Field Manual 3-7.[197,198]

When CWM is found or suspected at any MRS, the Army Technical Escort Unit (TEU), a division of the U.S. Army Soldier and Biological Chemical Command (SBCCOM), will assess any recovered non-stockpile CWM to determine if the materiel is explosive, whether it is fuzed, what its chemical composition is, and whether it is safe for movement, storage, treatment, or disposal. For each recovered munition, data are developed from systems such as the PINS and the DRCT (see Table 10-5). Data also are captured from any markings on the munition, the historical context of the find (World War I, World War II, Korean war era, etc.) and any eyewitness information. The data are then referred to a Materiel Assessment Review Board (MARB), chaired by the Commander of TEU. The MARB is responsible for evaluating available assessment data on suspect recovered CWM and making a final expert determination as to its explosive configuration and chemical fill.

10.7.2.1 *Preoperational Safety Surveys*

Before a chemical agent investigation or decontamination activity can begin, a preoperational safety survey is required in order to ensure that all safety aspects of the activity will be achieved. During the survey, all facilities, equipment, and procedures are certified, and operator proficiency in performing SOPs is demonstrated. This survey is conducted by the major command (MACOM)

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[197]NBC Field Handbook, Department of the Army Field Manual (FM) 3-7, September 1994.

[198]Toxic Chemical Agent Safety Standards, Department of the Army Pamphlet (DA PAM) 385-61, March 31, 1997.

or its designee, often the Army Technical Center for Explosives Safety (USATCES) Toxic Chemical Agent Team in the Chemical Safety and Data Division. The survey consists of a simulation of the planned activity by the operational personnel and their first line supervisor using dummy (inert) material. All Army regulations and provisions of the site plan and safety submission must be complied with during the survey.[199]

10.7.2.2 *Personnel Protective Equipment*

The DoD safety standard requires the use of administrative and engineering controls to minimize the personnel protective equipment (PPE) requirements (for example, the construction of a temporary seal over soils contaminated with chemical agents to reduce or eliminate the exposure potential to personnel). It is impossible to eliminate the need for PPE at all chemical agent sites. The level and types of PPE required should be specified in the health and safety plan.

In order to protect workers who may be exposed to chemical agents and to determine the appropriate level and type of PPE, the Army has set certain limits of chemical agent that a worker can be exposed to in 8-hour and 72-hour time-weighted shifts. AR 385-61 and the DoD Ammunition and Explosives Safety Standards (DoD 6055.9-STD) define these limits as the maximum permissible concentrations of chemical agent also known as the Airborne Exposure Limits (AELs), as established by the Army Surgeon General.

The levels of protection are identified in the regulatory requirements are as Levels A through F., with Level A is used for the most hazardous situations and Level F used in the most benign situations. Level A PPE involves wearing the maximum level of protection, which includes a toxicological agent protective (TAP) suit with a self-contained breathing apparatus, TAP boots, a hood, and gloves. Level F specifies that personnel carry a mask if they may be moving through clean storage or operating areas. Intermediate levels E through B require progressively more protection. These protection levels are designed by the Army and are specific to chemical agents. They do not match EPA's A-D levels of protection for hazardous waste. For more information on the Army's designation of PPE levels A through F see DA PAM 385-61.

10.7.3 Managing Chemical Agent Safety

Procedures for managing chemical safety require documentation of site safety and health plans and site safety submissions. Site safety submissions for chemical agent sites follow the same process as the explosives safety submission (ESS) review and approval process described in Chapter 6. However, because the Army is the lead agency for chemical safety, all safety submissions must be prepared or formally endorsed by the installation safety director and sent to the U.S. Army Technical Center for Explosive Safety (USATCES), which reviews, approves, and facilitates final approval by the DDESB.

[199] Ibid.

10.8 Conclusion

In accordance with the Chemical Weapons Convention, all stockpile chemical weapons and non-stockpile chemical warfare material and identified at the time of the ratification of the CWC and located in the United States must be destroyed by 2012. Although the United States is in the process of destroying all known stockpile and non-stockpile CWM, because of past disposal practices (e.g., burial) it is possible that CWM may still be present at former ranges, test areas and other sites. The presence of this materiel may present acute and chronic risks to human health and the environment.

When considering appropriate methods for detection, destruction and treatment of CWM, there are unique challenges that are encountered. Although the most common and effective method for remediation of CWM is item separation and incineration, this method has been publicly opposed because of possible health risks from emissions. The safety hazards imposed by the chemical agents and the explosive safety risks from the munition itself pose additional challenges. Safety requirements and common sense dictate that the explosive hazards be mitigated before the CWM is addressed.

As a result, the Army has developed a number of safety requirements and protocols that dictate how explosives CWM and RCWM are to be handled in order to minimize the risk to human health and the environment and have established a national program to tackle the problem of eliminating chemical weapons by 2012 and in so doing reducing the risks to human health and the environment.

Additionally, each service has regulatory requirements that follow the guidance provided to them by DoD's chemical and biological directives.

SOURCES AND RESOURCES

The following publications, offices, laboratories, and websites are provided as a guide for handbook users to obtain additional information about the subject matter addressed in each chapter. Several of these publications, offices, laboratories, or websites were also used in the development of this handbook.

Publications

CBRNE – Nerve Agents, Binary: GB2, VX2, Velez-Daubon, Larissa I., MD, Fernando L Benitez, MD. eMedicine Journal 3:1, January 2002. 3:1, http://www.emedicine.com/emerg/topic900.htm.

Chemical Agent Data Sheets, Volumes I and II, Edgewood Arsenal Special Report No. EO-SR-74001, December 1974. Available through Defense Technical Information Center, DTIC No. AD B028222.

Hartman, H.M. ***Evaluation of Risk Assessment Guideline Levels for the Chemical Warfare Agents Mustard, GB, and VX.*** Regulatory Toxicology and Pharmacology, 35, pp. 347-356, 2002.

Munro, N.B. et al. ***The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products.*** Environmental Health Perspectives, Vol. 107, No. 12, December 1999.

Munro, N.B. et al. ***Toxicity of the Organophosphate Chemical Warfare Agents GA, GB, and VX: Implications for Public Protection.*** Environmental Health Perspectives, Vol. 102, No. 1, January 1994.

NAP (National Academy Press). ***Review of Acute Human-Toxicty Estimates for Selected Chemical-Warfare Agents.*** National Research Council, National Academy Press, 1997.

NAP. ***Review of the U.S. Army's Health Risk Assessments for Oral Exposure to Six Chemical Warfare Agents.*** National Research Council, National Academy Press, 2000.

NAP. ***Systems and Technologies for the Treatment of Non-Stockpile Chemical Warfare Agents.*** National Research Council, National Academy Press, 2002.

NAP. ***Veterans at Risk: The Health Effects of Mustard Gas and Lewisite.*** Institute of Medicine, National Academy Press, 1993.

Roberts, W.C., and W.R. Hartley. ***Drinking Water Health Advisory: Munitions.*** CRC Press, Boca Raton, FL, 1992.

Somani, S.M., and J. Romano, ***Chemical Warfare Agents: Toxicity at Low Levels.*** CRC Press, Boca Raton, FL, 2001.

U.S. Army. ***Non-Stockpile Chemical-Material Program, Survey and Analysis Report.*** U.S. Army Chemical Materiel Destruction Agency, November 1993.

U.S. Army Armament, Munitions and Chemical Command Chemical Research, Development and Engineering Center. Material Safety Data Sheet: Lethal Nerve Agent Tabun (GA).

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). ***Detailed and***

General Facts About Chemical Agents, TG 218.

U.S. Army Chemical Biological Defense Command Edgewood. Material Safety Data Sheet: Lewisite. Last Technical Review on May 5, 1999.

U.S. Army Corps of Engineers. ***Safety and Health Requirements Manual.*** EM 385-1-1, Washington, D.C., September 3, 1996.

U.S. Army Soldier and Biological Chemical Command (SBCCOM). Material Safety Data Sheets. Revised on August 13, 2001.

Information Sources

Agency for Toxic Substances and Disease Registry (ATSDR)
ATSDR Region 1
1 Congress Street
Suite 1100 HBT
Boston, MA 02114
(617) 918-1494
http://www.atsdr.cdc.gov/mmg.html

Deployment Health Clinical Center (DHCC)
Blister Agent Fact Sheet
http://pdhealth.mil/wot/chemical.asp

International Programme on Chemical Safety (IPCS INCHEM)
World Health Organization (WHO)
20 Avenue Appia
1211 Geneva, Switzerland
http://www.inchem.org/pages/icsc.html

Mitretek Systems
3150 Fairview Park Drive
Falls Church, VA 22042-4519
(703) 610-2002
http://mitretek.org/home.nsf/homelandsecurity/chembiodefense

National Institute for Occupational Safety and Health (NIOSH)
(800) 35-NIOSH
http://www.cdc.gov/niosh/homepage.html

National Toxicology Program (NTP)
P.O. Box 12233, MD EC-03
Research Triangle Park, NC 27709
(919) 541-3419
http://ntp-server.niehs.nih.gov/

Organization for the Prohibition of Chemical Weapons, Chemical Weapons Convention
http://www.opcw.org/html/db/cwc/eng/cwc_frameset.html

University of Oklahoma, College of Pharmacy
1110 N. Stonewall Avenue
Oklahoma City, OK 73117
(405) 271-6484
http://www.oklahomapoison,org/prevention/arsine.asp

U.S. Army Center for Explosives Safety (USATCES)
1 Tree Road, Building 35
McAlester, OK 74501
http://www.dac.army.mil/es/

U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM)
5158 Blackhawk Road
Aberdeen Proving Ground, MD 21010
(800) 222-9698
http://chppm-www.apgea.army.mil/

U.S. Army Chemical Materials Agency Headquarters
Public Affairs
AMSCM-SSP
5183 Blackhawk Road
Aberdeen Proving Ground-Edgewood Area, MD 21010-5424
(800) 488-0648
http://www.cma.army.mil/home.aspx

U.S. Department of Labor, Occupational, Safety and Health Administration (OSHA)
200 Constitution Avenue
Washington, D.C. 20210
1-800-321-OSHA
http://www.osha.gov

U.S. Army Engineering and Support Center, Huntsville
Directorate of Chemical Demilitarization
ATTN: CEHNC-CD
P.O. Box 1600
Huntsville, AL 35807-4301
(256) 895-1370
http://www.hnd.usace.army.mil/chemde/index.asp

U.S. National Library of Medicine, Specialized Information Services
2 Democracy Plaza
Suite 510 6707 Democracy Boulevard, MSC 5467
Bethesda, MD 20892
(301) 496-1131
http://sis.nlm.nih.gov/

Guidance Documents

Chemical Accident or Incident Response and Assistance (CAIRA) Operations. DA PAM 50-6, Headquarters, Department of the Army, Washington, D.C., May 1991.

U.S. Army. Army Chemical Safety Program, AR 385-61, Headquarters, Department of the Army, Washington, D.C., February 1997.

U.S. Army. Chemical Surety, Army Regulation 50-6, Headquarters, Department of the Army, Washington, D.C., February 1995.

U.S. Army. ***DoD Ammunition and Explosives Safety Standards.*** DoD 6055.9-STD.

U.S. Army. ***Military Chemistry and Chemical Compounds.*** Army Field Manual (FM) 3-9, Air Force AFR 355-7, Headquarters, Department of the Army, October 1975.

U.S. Army. NBC Field Handbook, Field Manual (FM) 3-7, Headquarters, Department of the Army, Washington, D.C., September 29, 1994.

U.S. Marine Corps. NBC Decontamination, FM 3-5, Headquarters, Department of the Army, MCWP 3-37.3, Commandant, Washington, D.C., July 28, 2000.

FM 4-30.13 (FM 9-13)

AMMUNITION HANDBOOK: TACTICS, TECHNIQUES, AND PROCEDURES FOR MUNITIONS HANDLERS

HEADQUARTERS
DEPARTMENT OF THE ARMY

DISTRIBUTION RESTRICTION: Approved for public release; distribution is unlimited.

004120

PREFACE

This field manual provides ready reference and guidance for units and soldiers that handle munitions items. It is not a comprehensive manual, but it does provide useful data on important points of munitions service support. Also, it is a training tool for munitions units and soldiers.

Focus is on tactics, techniques, and procedures used by soldiers handling munitions. The information and guidance contained herein will help them to safely receive, ship, store, handle, maintain, and issue munitions. The manual provides information on processing unit turn-ins, destroying unserviceable munitions, and transporting munitions in new, maturing, or mature theaters of operations in support of the force projection Army. The information in this manual conforms to the procedures of MOADS, MOADS-PLS, and modularty, and will take munitions units well into the twenty-first century.

The proponent for this publication is United States Army Combined Arms Support Command & Ft Lee (USACASCOM&FL). Send comments and recommendations on DA Form 2028 (or in 2028 format) directly to Commander, USACASCOM&FL, Directorate of Combat Developments, ATTN: ATCL O, 3901 A Avenue, Suite 250, Fort Lee, VA 23801-1809.

***FM 4-30.13**

Field Manual
No. 4-30.13

Headquarters
Department of the Army
Washington, DC, 1 March 2001

Ammunition Handbook: Tactics, Techniques, and Procedures for Munitions Handlers

Contents

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Chapter 1

Tactical Unit Operations

This chapter discusses munitions support and tactical unit operations within the theater structure. Munitions directly impact the success of tactical operations. It is the function of ammunition companies and modular ammunition platoons in the theater of operations to best support the operational plans of tactical commanders. Ammunition unit tactical-level operations include activities necessary to support and win in combat as well as activities that precede and follow them.

STRATEGIC, OPERATIONAL, AND TACTICAL FUNCTIONS

1-1. *Power projection* is the ability of a military force to deploy air, land, and sea forces to any region of the world and to sustain them for any type of mission. Power projection is a central strategic concept of US military strategy. *Force projection*, the Army's contribution to this joint effort, is the demonstrated ability to rapidly alert, mobilize, and field a force that is deployable, lethal, versatile, expandable, and sustainable.

1-2. Army CSS operates in a seamless continuum throughout the strategic, operational, and tactical environments. *Strategic* CSS maintains the national sustainment base and supports force projection. *Operational* CSS accomplishes operational plans by linking tactical requirements to strategic capabilities. Operational level support personnel are aware of the combat commander's theater strategic perspective and requirements at the tactical level. *Tactical* CSS focuses on coordinated, tailored warfighter support by manning, arming, fueling, fixing, moving, and sustaining the soldier and his equipment. The following section briefly describes theater structure to provide context for the discussion of tactical unit operations.

THEATER STRUCTURE

1-3. A theater is a geographical area located OCONUS for which a commander is assigned military responsibility. International military cooperation and the degree of dedicated US forces influence how the Army conducts operations in each theater.

THEATER OF WAR

1-4. When combat operations are authorized, a strategic theater of war is delineated. It may include part or all of the original peacetime theater. Part of the theater may be in a state of war while other areas remain at peace.

THEATER OF OPERATIONS

1-5. To contend with more than one threat, the theater of war may be subdivided into subordinate theaters or areas of operation. Theaters of operation are those portions of an area of war required for military operations and for administering those operations.

COMMUNICATIONS ZONE

1-6. The COMMZ extends from the rear of the combat zone in the theater of operations to the CONUS base. Its size depends on the size of the theater of operations and the size of the force required for operation and sustainment. Within the COMMZ is the theater logistics base. It contains logistic facilities needed to support the theater; these include APOD/SPOD, storage areas, logistics headquarters, and units essential to munitions support.

CORPS/DIVISION OPERATIONS

1-7. A corps and/or division(s) operates in a defined theater as a forward presence to deter or combat threats. A corps normally fights as an element of a joint/combined or multinational force in cooperation with the Air Force, Navy, Marine Corps, and allied forces. It is tailored for the theater and mission operations and can fight only as long as the COSCOM provides munitions and logistical support.

MUNITIONS SUPPORT

1-8. Munitions units are required to provide support for SASO and offensive, defensive, and contingency operations. Also, they support other missions as assigned in both theater and corps areas of operation.

OFFENSIVE OPERATIONS

1-9. Logistic assets, including ammunition companies/platoons, are essential to maintaining the momentum of offensive operations. The corps goal is to support maneuver and CS units engaged in the main battle. Units that handle, store, and supply munitions must be mobile and prepared to move as often as the combat force requires. Types of offensive operations include movement to attack, hasty attack, deliberate attack, exploitation, and pursuit.

DEFENSIVE OPERATIONS

1-10. At any time, combat units defend, delay, move out of contact, or execute withdrawals. The object of defensive operations is failure of an enemy attack. Defensive operations also allow US forces to gain time, to concentrate elsewhere, to hold key objectives, or to wear down the enemy before going on the offensive. Types of defensive operations include support of a covering force, main battle force, or a mixture of heavy, light, and reserve forces.

CONTINGENCY OPERATIONS

1-11. US forces may be required to serve as a contingency force in an undeveloped area where a US military infrastructure does not exist. Such an operation typically might be one in which an undeveloped, friendly HN requests military assistance. A contingency force would conduct combat operations short of war but necessary to defeat threat forces or expel them from occupied territory. The size of this force would be tailored to the threat and the environment. Initially, it could be smaller than a division but could be expanded rapidly. The munitions support structure would also be tailored and, depending on METT-TC, may include only elements of DS companies or modular ammunition platoons to operate ASPs or ATPs.

STABILITY AND SUPPORT OPERATIONS

1-12. SASO may be necessary to maintain a negotiated truce or to achieve, restore, or maintain a diplomatic resolution or peace in a hostile area or an area of potential conflict. Forces involved in such operations are traditionally multinational. The munitions force structure may be tailored to support both US and multinational forces for short or extended periods in a bare-base environment in conjunction with HNS. Most likely, the munitions force would consist of DS companies, modular ammunition platoons, or ammunition transfer point sections.

ORGANIZATION FOR AMMUNITION SUPPORT

1-13. The munitions force structure is evolving. This should be remembered, regardless of the type of operation ammunition units are required to support. In the near term, and well into the twenty-first century, ammunition units will continue to become smaller in size. At the same time, they will become more flexible and capable of deploying more rapidly, operating more efficiently at higher levels of productivity. This process will be in cooperation with elements from other services, multinational forces, other governmental and nongovernmental organizations, DOD civilians, and contract personnel.

MODULARITY

1-14. The structure of ammunition units and the munitions support concept is revised as combat doctrine evolves. MOADS doctrine and force structure were designed to support a forward-deployed force. In the near future, MOADS will transition to a more flexible distribution system based on the concept of modularity. A munitions structure based on modularity will more effectively meet the needs of a force projection Army. Under this concept, only the number of soldiers, DOD civilians, and the equipment needed to support the force are deployed.

1-15. The advent of modular munitions units has drastically increased the flexibility of the ASCC and joint commanders during combat and SASO. Unlike MOADS-PLS units, modular companies and platoons are 100 percent mobile (less munitions stocks). This mobility is particularly important for split-based and contingency operations. The ability of a modular platoon to deploy independent of its company headquarters allows the ASCC to right-size his forces for combat and SASO. Although modular platoons and companies are 100 percent mobile, they *are not* 100 percent sustainable. These units must be attached to a higher headquarters (i.e., company or battalion) for administrative and logistical support and C2.

1-16. The following sections provide a general overview of the typical ordnance company/battalion structure. The C2 structure in a tactical environment may not follow a functional “stovepipe” alignment. Modular ammunition platoons may be required to operate independent of their companies and within a C2 structure that is multifunctional, particularly at battalion and higher.

COMPANY STAFF AND RESPONSIBILITIES

1-17. The company typically has a rudimentary structure and relies on its parent battalion for CSS assets. Key personnel within the structure have major responsibilities that impact unit operations. These personnel, along with their duties and responsibilities are discussed below. Ammunition TOE must be consulted for specific type units.

Company Commander

1-18. The company commander is responsible for unit training, safety, and discipline and directs and supervises all phases of operations and employment. The CO is advised and assisted by his officers and NCOs. Among the most important duties and responsibilities of the company commander are the following:

- Leads, plans, directs, and supervises company operations; guides the unit in carrying out its mission.
- Establishes unit policies and procedures.
- Establishes and maintains operations security consistent with guidance from higher headquarters.
- Initiates and ensures adherence to the unit safety program.
- Ensures that unit readiness is maintained.

1-19. The company commander must be personally involved in planning and carrying out unit training IAW FM 25-100 and FM 25-101. Other related duties include the following:

- Performs periodic inspections to determine unit readiness.
- Stresses principles of accountability and maintenance.
- Instructs and cross-trains subordinates.

Executive Officer

1-20. The XO coordinates administrative and logistical support for the company. In the absence of the commander, the XO is in command. During modular or split-based operations, the XO takes command of the portion of the company in the rear location. Supervision of internal security and coordination with the battalion staff are among the XO's responsibilities.

First Sergeant

1-21. The first sergeant is the senior NCO in the company and assists the company commander in carrying out his responsibilities. The first sergeant must fully understand the company's mission and be able to adjust administrative requirements to accomplish that mission. First sergeant duties include the following:

- Calls formations.
- Manages the company headquarters.
- Coordinates company headquarters.
- Serves as intermediary between the commander and unit enlisted personnel.

- Assumes duties of the commander in the absence of all other officers.
- Plans and posts company details in cooperation with operational personnel.
- Maintains duty rosters.
- Exercises supervisory responsibility over housekeeping, work details, police, maintenance, and construction projects in the company areas.
- Assists the commander in advising enlisted personnel on personal matters.
- Advises the company commander on personnel and morale problems.

Ammunition Warrant Officer

1-22. The ammunition warrant officer at the company level is responsible for all technical aspects of munitions operations. His primary focus is the safe receipt, storage, and issue of munitions stocks in support of the operation designated by the ASCC or joint commander. He instructs unit personnel in all aspects of munitions operations. He normally serves as the accountable officer or storage officer for all munitions stocks stored by the company. He will also act as the accountable officer for stocks held by a platoon during split-based operations. During split-based operations he may assume more administrative duties while serving as second in command to the platoon leader. Also, he may be called on to provide technical and munitions doctrinal advise to the ASCC as one of the senior munitions logisticians in the AO. Other specific duties of the ammunition warrant officer include–

- Directs and coordinates destruction and demilitarization of conventional ammunition, missile explosive components, and other explosive items.
- Directs and coordinates surveillance tests, modifications, and maintenance of conventional ammunition, missile explosive components, and other explosive items in coordination with QASAS/qualified military ammunition inspectors.
- Supervises and manages SAAS-MOD (ASP) and its associated ADP equipment.
- Prepares and/or reviews ammunition storage waivers.
- Prepares, reviews, and/or implements firefighting procedures.
- Plans, reviews, and/or implements emergency destruction of ammunition, missiles, and other explosive items.
- Manages, examines, interprets, disseminates, and verifies requirements for ammunition technical publications in the unit.
- Plans for and schedules work requirements, observes work practices, detects and corrects unsafe or improper procedures and techniques.
- Ensures ammunition QA/QC procedures are followed.

Automotive Maintenance Warrant Officer

1-23. The automotive maintenance warrant officer is responsible for maintaining unit automotive equipment and training and supervising maintenance personnel. The maintenance tech coordinates with maintenance support units and performs the following duties:

- Manages the unit maintenance program.
- Assists and advises the company commander in assigning maintenance personnel.
- Advises the commander on maintenance matters and problems.
- Prepares the maintenance portion of the unit SOP.
- Ensures that replacement parts are available or are on request.
- Conducts maintenance inspections, supervises maintenance inspections, and ensures that records are maintained.

Motor Sergeant

1-24. The motor sergeant is chief assistant to the maintenance officer and responsible for the proper maintenance of unit vehicles. The motor sergeant is supervised by the automotive maintenance warrant officer. He assists in organizing the maintenance program and operates it IAW sound maintenance procedure, as follows:

- Assigns tasks.
- Implements work schedules established by the maintenance officer.
- Inspects work performed by unit mechanics.
- Enforces safety practices.

Platoon Leader

1-25. Much like platoon leaders in any military unit, the munitions unit platoon leader is responsible for training and discipline. Also, the platoon leader of a munitions unit supervises personnel in munitions storage, receipt, issue, and maintenance operations.

1-26. The platoon leader ensures that the platoon carries out the company commander's instructions. He trains the platoon with a dual purpose. First, the platoon must be developed and trained as part of the company team. Second, the platoon must be trained to be self-reliant since it may be detached from the company and operated as a separate unit. In the latter case, the platoon leader functions as commander of an independent detachment and is responsible for the administration, operation, supply, and security.

1-27. The platoon leader must be encouraged to develop and exercise the command and leadership qualities required of the position. When the company operates as a unit, the platoon leader has added duties assigned by the company commander. These duties may include the following:

- Supervising the training of soldiers in all phases of their duties, including maintenance services.
- Inspecting platoon members' individual clothing and equipment for serviceability and availability.
- Inspecting platoon billets and areas to ensure that standards of cleanliness and sanitation are kept.
- Preparing a daily availability report of platoon personnel.
- Enforcing discipline and internal control during convoy operations.

- Conducting preliminary investigations and preparing reports related to accidents.
- Enforcing environmental laws and regulations.
- Instructing the platoon or company as prescribed by the unit training schedule.
- Organizing, in coordination with other platoons, defense of the platoon AO, preparing and submitting sketches of the defense plan to the unit commander.
- Undertaking additional duties (such as security officer, investigating officer) as may be assigned by the appointing authority.
- Informing the unit commander of all phases of platoon training and operations; discussing with and advising the company commander on matters regarding training and operations.

Platoon Sergeant

1-28. The platoon sergeant is the assistant to the platoon leader. He assists with the training of the platoon and supervises both tactical and technical operations. Through section sergeants, the platoon sergeant directs and supervises munitions operations, unit maintenance, and tactical operations; trains soldiers in the operation and care of motor vehicles and MHE; and assumes the duties of the platoon leader in the absence of the platoon leader and warrant officer. The platoon sergeant also—

- Coordinates the duties of his section sergeants.
- Inspects storage locations to ensure compliance with regulatory requirements.
- Supervises, through his section sergeants, the performance of unit level maintenance of assigned equipment.
- Inspects vehicles and BIIs for accountability and serviceability.
- Coordinates with the motor sergeant for the repair of vehicles and equipment that need service beyond the drivers' capability.
- Coordinates section training and operational activities.
- Coordinates platoon operations.
- Inspects the platoon defensive perimeter and bivouac site and takes corrective action.
- Enforces safety rules and techniques.
- Enforces environmental laws and regulations.

Section Sergeant

1-29. The section sergeant is directly responsible to the platoon sergeant for the training, discipline, appearance, and performance of assigned soldiers. He directs section personnel in storage operations, safe driving and MHE operating practices, and maintenance of equipment records. Among other duties, the section sergeant—

- Maintains a record of availability of personnel and equipment under his control.

- Ensures that each soldier is familiar with his part in storage operations.
- Supervises the performance of vehicle and equipment maintenance.
- Reports to the platoon sergeant the mechanical defects beyond the soldiers' ability to repair.
- Ensures that living areas meet proper standards of cleanliness.
- Enforces environmental laws and regulations.

BATTALION STAFF AND RESPONSIBILITIES

1-30. Battalions are authorized a headquarters staff organized to meet unit requirements. Staff activities must focus on assisting the commander and will contribute to mission accomplishment. Munitions units may not always be subordinate to an ordnance battalion. Battalion and higher CSS organizations are largely multifunctional and capable of delivering nearly total support. This allows units to deal with a single point of contact for support. Munitions units may be assigned to either a corps support battalion or ordnance battalion. Battalions without organic ammunition surveillance support may be augmented with QASAS personnel upon or after deployment.

Battalion Commander

1-31. The battalion commander commands the battalion and all attached units. He administers, supervises trains, directs, controls, and coordinates activities of the battalion and attached units. Other responsibilities of the battalion commander include:

- Planning for, making decisions concerning, and publishing orders and directives governing personnel, discipline, operations, training, supply, and maintenance matters.
- Evaluating and estimating the needs of the organization.
- Supervising the execution of orders and inspecting completed assignments.
- Upholding environmental protection standards by conducting all training and operations IAW relevant environmental regulations, SOFAs, and SOPs.
- Ensuring that risk management and safety procedures are incorporated in all operations.

Executive Officer

1-32. The XO is second in command. He assists the commander in all phases of work and takes command in the commander's absence. The XO assists in interpreting, formulating, and disseminating policy. He takes the commander's decisions to the appropriate staff officers to prepare necessary staff directives. Also, the XO—

- Exercises staff supervision and direction over all operations and training.
- Formulates and announces policies for general operation of the staff.
- Ensures that the commander's orders and instructions are carried out through personal observation and inspection.

- Studies continually the overall operation of the battalion headquarters and subordinate units.
- Functions as the principal staff-coordinating agent of the battalion.

Operations Officer

1-33. The S3 handles staff matters pertaining to operations, training, security, and intelligence. He prepares and coordinates operational plans for the battalion and subordinate units and coordinates planning activities of subordinate units. To accomplish his mission, the S3 performs the following duties:

- Prepares operational SOPs and coordinates them with higher and subordinate units.
- Maintains operational records and statistical reports.
- Conducts liaison with supported agencies and activities.
- Maintains centralized operational control over subordinate units.
- Studies plans and operations on a regular basis and prepares estimates, plans, and directives.
- Assigns workloads and specific operational tasks to subordinate units.
- Plans and supervises training for the battalion and subordinate units.
- Conducts training inspections.
- Maintains contact and exchanges information with security and intelligence personnel of higher, adjacent, and subordinate units.
- Receives and distributes intelligence information.
- Directs and supervises OPSEC and advises the commander on operational, security, and training matters.
- Prepares and publishes security directives.
- Make security inspections of battalion and subordinate units.
- Prepares and distributes security and intelligence SOPs.
- Coordinates and supervises security and defense measures for the battalion and subordinate units (with the executive officer).
- Requests road clearance for convoys and movement of oversize loads.
- Coordinates and monitors subordinate unit environmental risk assessments and advises the commander on their status and outcome.

S3 Operations Sergeant

1-34. The battalion S3 operations sergeant is the senior NCO in the operations section. He supervises the duty performance of the section's enlisted personnel. Other duties of the operations sergeant are as follows:

- Assists the operations officer and ensures that administrative policies and procedures are properly carried out.
- Coordinates the functions of the operations section.
- Maintains statistics on operational capabilities and performance of subordinate units.
- Establishes and maintains liaison with supported units and activities.

- Supervises documentation and report procedures and performs such other duties as directed by the operations officer.

Supply Officer

1-35. The S4 maintains accountability for operation and maintenance funds. He also coordinates supply activities with higher headquarters and supporting services and prepares and coordinates supply SOPs and directives. Other duties of the S4 are as follows:

- Monitors priorities assigned to requisitions by battalion units as well as submission of requests to supporting supply activities.
- Consolidates requisitions submitted by subordinate units.
- Receives supplies, establishes schedules for issue, and issues supplies.
- Designates POL points and makes distribution of POL.
- Supervises and inspects subordinate unit supply procedures and records.
- Establishes, supervises, and directs the food service program.
- Establishes and maintains liaison with supporting services and activities.
- Prepares and supervises maintenance of battalion property records and accounts.
- Procures, allocates, and releases billet areas, buildings, and other facilities used by all battalion elements.

The S4 advises the commander concerning supply, mess, and real estate matters; property accountability within the battalion; contracting; and matters pertaining to munitions and hazardous materials.

Materiel Officer

1-36. An ordnance battalion TOE typically includes a materiel section supervised by a materiel officer. This section monitors munitions support requirements and the operational ability of subordinate ordnance units but does not manage munitions stocks. The MATO advises the commander on munitions support planning and equipment and the personnel status of subordinate units. He monitors the equipment and personnel status of subordinate units and recommends actions to maintain support capability. He recommends actions to maintain mission support capability. In a CSB, the support operations officer may assume this function with assistance of a COSCOM materiel management team.

MATO Ammunition Warrant Officer

1-37. The ammunition technician (ammunition warrant officer) at the battalion level is assigned to the materiel section. He is normally the senior ammunition warrant officer in the battalion and is the principal technical advisor to the battalion commander and the materiel officer on requirements for munitions support planning. He monitors equipment and personnel status of subordinate units and recommends actions to maintain support capability. He also monitors the stock status of SSAs, ensures that subordinate units are conducting safe and efficient operations IAW SOPs, and ensures compliance with theater reporting requirements and munitions policy. As a senior munitions logistician, he may be called on to provide technical and doctrinal advice to the ASCC or joint commander in a contingency or SASO environment.

MATO Operations Sergeant

1-38. The MATO operations sergeant is the senior NCO assigned to the MATO. He supervises the duty performance of the assigned enlisted personnel. He assists the materiel officer and the ammunition warrant officer and ensures those administrative policies and procedures are properly conducted. The MATO operations sergeant maintains statistics on ammunition support performance and the capabilities of assigned ammunition companies and/or platoons. He manages subordinate unit through higher headquarters reporting procedures. Also, he performs other duties as directed by the materiel officer and ammunition warrant officer. Under certain TOE, the MATO operations sergeant's duties may be combined with those of the battalion S3 operations sergeant.

TACTICAL MOVEMENT OPERATIONS

1-39. Units are required to plan and execute tactical operations when moving to a new location. When a move is to be made, site selection, area preparation and layout, defense, security, and area damage control are important considerations. The warning order for displacement normally includes the general area in which the unit will conduct future operations, the movement date, and a list of any special requirements or instructions deemed necessary. Upon receipt of notification of impending move, the company commander alerts unit personnel and begins planning for the move.

SOP PREPARATION

1-40. A detailed field SOP must be prepared to cover movement operations. To ensure a successful move under stressful conditions, units must train on movement operations until they become proficient. The following items must be addressed in the field SOP:

- Organization of march units.
- Organization and duties of the advance party, the rear party, and reconnaissance element.
- Densities and speeds for different types of moves.
- Control measures.
- Actions in event of enemy attack.
- Refueling procedures.
- Mess procedures.
- Communications methods.
- Vehicle loading plans for personnel and equipment.

TRANSPORTATION

1-41. Units organized under the MOADS-PLS TOE have limited mobility. Since organic transportation is not sufficient to permit movement of the unit in one lift, additional transportation must be requested. Transportation requests are normally made to the battalion headquarters operations section. The operations section places the requirement with the supporting MCT. The request will contain the following relevant information:

- Date of move.
- Routes.
- Destination.
- Time and place transportation is required.
- Number of personnel to be moved.
- Quantity, type, weight, and volume of materiel to be moved (see FM 55-30).

Modular units are fully capable of moving all TOE equipment and personnel, less munitions stocks. Both MOADS-PLS and modular units require augmentation to move munitions stocks stored in their locations.

AREA SELECTION

1-42. The area selected for unit operations must be capable of being defended, yet suitable for technical operations. Often these considerations are not compatible, and defense risks must be weighed against the operational mission. An alternate area is selected in case the unit position becomes unsustainable due to enemy action or effects of weather on the terrain.

AREA LAYOUT

1-43. Area layout requirements for each unit vary according to the tactical situation, the proximity to forward areas, and the type and amount of munitions handled. A good layout is one that achieves the following:

- Facilitates the workflow.
- Minimizes the movement of munitions, tools, and equipment.
- Permits easy entry and exit for heavy traffic.
- Provides for effective control of unit operations.
- Permits defense of the area.
- Provides for easy access to a communications node.

Proper positioning of weapons, construction of defensive works and obstacles, organization of unit defense, and security are prime considerations.

1-44. An overlay is prepared to include the defense plan and operational layout for new area. If appropriate, route overlays or schematic diagrams are also prepared. The overlays are used by the advanced, main, and rear parties. A copy is submitted to higher headquarters.

RECONNAISSANCE

1-45. After the new area is selected, the commander or platoon leader makes a personal reconnaissance of the route to the new area. If this is not possible, a map reconnaissance is made. The route, the surrounding terrain, and road network in the new area must be evaluated for suitability. The following route characteristics must be noted:

- Strength and clearance of underpasses.
- Durability, capacity, and width of roads and bridges.
- Terrain characteristics that would favor an ambush of the convoy.

A thorough reconnaissance is extremely important, as the results determine planning for the unit move, and may dictate the use of alternate routes.

ADVANCE PARTY

1-46. Once reconnaissance of the route and new area is complete, an advance party is dispatched to prepare the area for occupancy and to mark the route. The advance party usually consists of personnel representing all sections of the unit. The number of personnel included must be sufficient to carry out the following tasks:

- Clear the route of obstacles and warn the main body of known or suspected enemy activity along the route.
- Check the area for chemical contamination by conducting monitoring operations, if required.
- Place route markers.
- Provide platoon and section guides from the release point to guide vehicles to their assigned areas.
- Secure the area.
- Check area for mines, booby traps, and enemy activity.
- Set up and man temporary outposts.
- Lay communication wire from the CPs to the defense positions and work areas.
- Prepare positions for crew-served weapons.
- Prepare hasty fortifications to cover likely avenues of approach.

PRIORITY OF ACTIONS

1-47. After moving into the new area, the commander of the battalion headquarters is informed of the new location. The commander is briefed on the situation in the area, the units supported, and any problems or specific requirements relating to the support mission. Other tasks to be performed upon arrival in the area include the following:

- Complete perimeter defense and coordinate with base defense operations center or base cluster operations center.
- Prepare for operations and concurrently establish liaison with supported units.
- Complete billeting for unit personnel.
- Coordinate defenses with adjacent units.

REAR PARTY

1-48. The rear party closes out operations in the old area. Composition of the party depends upon the work required to complete these operations. Communication is maintained between the rear party and higher headquarters until the CP in the new area becomes operational.

UNIT DEFENSE AND SECURITY

1-49. Detailed planning and training in conducting defense operations is required. Rapidly moving tactical operations, pockets of enemy resistance, and enemy infiltration that result from widely spread tactical formations are the rule rather than the exception. Units in rear areas are targets of enemy actions.

1-50. Defense planning must take into account all technical mission requirements so that operations will run as smoothly as possible in adverse conditions. Plans to meet any type of enemy attack will be incorporated in the unit security SOP. These plans are revised as necessary and are rehearsed regularly to ensure that all individuals know their duties and responsibilities.

1-51. At times, defense of a conventional ammunition unit will be at the expense of mission activities. The commander must continually evaluate mission requirements in light of the enemy situation. Security must provide early warning to allow unit personnel sufficient time to move to prepare defensive positions and reserve assembly areas.

Defense Plan

1-52. A defense plan is published as an integral part of the unit security SOP. The RAOC reviews and coordinates defense plans and area damage control plans. The defense plan includes all routine security and defense activities/procedures to include:

- Designation of specific responsibilities.
- Primary and alternate means of communications.
- Emergency destruction procedures.
- Coordination and identification of mutually defensive procedures with local unit higher headquarters.
- Active and passive individual and unit security and defense measures, such as communications security, operations security, and noise and light discipline.
- NBC defenses.

1-53. The defense plan must incorporate the fundamentals of defense. However, these fundamentals will be adapted to the peculiarities of the ammunition unit. At minimum, the plan must detail procedures and responsibilities, including the following:

- Surveillance and security.
- Organic and supporting weapons.
- Preparation of positions.
- Communications.

- Reserve forces such as QRF or TCF.
- Rear area protection.
- NBC defense plan.

1-54. The ASCC and others commanding joint operations must understand that the requirements and size of munitions operations will demand some type of augmentation for physical security of an ASA. This does not absolve the ammunition unit commander of the responsibility to plan and coordinate the ASA defense. Often, due to the scale of the operation, the ammunition unit commander is the base or base cluster commander responsible for security of the entire base.

AREA DAMAGE CONTROL

1-55. The unit commander develops an area damage control plan as part of the defense plan. The plan lists those measures to be taken by the unit before, during, and after an attack or natural disaster. The area damage control plan addresses actions required in the event of an NBC attack, including composition of the NBC monitoring and decontamination teams. The object of this plan is to minimize casualties and destruction, speed recovery, and reestablish support.

1-56. Planning, training, and practice alerts must be conducted before an attack or natural disaster occurs. Dispersion, camouflage, construction of fortifications and emplacements, and other actions common to defensive operations must be covered if training is to be effective. During the attack or disaster, emphasis is on survival and assistance to the injured. After the attack the emphasis is on resuming operations, which includes the following:

- Regaining control.
- Assessing damage.
- Treating and evaluating casualties.
- Clearing isolated and danger areas.
- Conducting chemical agent detection and radiological monitoring and surveys and reporting results.
- Conducting salvage and emergency resupply operations.
- Reestablishing communications.

1-57. Furthermore, the unit must remain alert to the possibility of a follow-up attack by enemy forces. The unit must be prepared to defend itself and to provide personnel to area damage control forces. Regular enemy forces may try to surprise or capitalize on the surprise and confusion caused by an attack or disaster. The unit must be capable of quick and proper action. Company plans for area damage control must be a part of the battalion plan. The area security controller coordinates these plans with other units and is responsible for preparing and implementing plans for a specific area. The battalion or the RAOC may direct that unit plans be modified. Battalion headquarters provides instructions on submitting unit plans and necessary modifications to the submitted plans.

SUMMARY

1-58. Offensive, defensive, and contingency operations and SASO discussed earlier in this chapter require that munitions units be capable of conducting efficient tactical moves. This efficiency ensures that personnel and equipment are in the right place at the right time to support mission requirements. Other chapters in this manual discuss specific technical support requirements that must be completed to provide safe, efficient, and timely supply of munitions to the user. The command must emphasize training and leadership at all levels to ensure that munitions units are thoroughly familiar with munitions support in a tactical environment.

Chapter 2

Planning Combat and Stability and Support Operations

This chapter describes general ammunition planning considerations necessary to support combat operations and/or SASO. It includes development of contingency plans and SOPs, prepacking of unit material, transportation for unit movement, retrograde of ammunition, and transitions to and from combat operations or SASO.

DEFINING COMBAT AND SASO MISSIONS

2-1. The term, *combat operations*, is generally used to describe both war and contingency operations. War is a major conflict between nations employing total resources and may be of a limited or general nature. Generally, war involves large-scale combat operations for an indefinite period until a favorable conclusion is reached.

2-2. The term, *contingency*, is generally used to describe a crisis, often with complex political implications, that may happen anywhere in the world where US interests are threatened. Such a crisis may lead to hostilities where the military mission and threat may not be specifically defined but where strategic objectives are identified. Although contingencies may evolve slowly, the decision to use a military option may be made with short notice. Contingency operations are expected to be of short duration with a quick, clear victory. They almost always take place in a new or a maturing theater where there are either no or few established US forces. In combat operations, US services may be fighting as part of joint or combined forces with allied participation.

2-3. The term, *stability and support operations*, is generally used to describe the use of armed forces to help keep tensions between nations below the level of conflict. Typical operations include disaster relief, nation assistance, security and advisory assistance, counter-drug operations, arms control, treaty verification, support to civil authorities, and peacekeeping. In this manual, combat operations and SASO are synonymous for Class V support operations. The main differences are the nature of the activity, the size and structure of the combat force, the support structure on the ground, and METT-TC.

2-4. Future military operations will require that ammunition units be effective and efficient, highly mobile organizations. Battles may be nonlinear and require rapid movement, multiple relocations, and the ability to support and sustain maneuver forces in a variety of mission profiles. Thus, ammunition support units must be capable of adapting to many scenarios and configurations. Depending on the size of the supported force, an ammunition unit may conduct support operations in either a company or modular configuration. Modular configurations will be used based on operational needs. This may mean that a single modular platoon could be deployed to support a brigade contingency, or a number of platoons and/or companies could be deployed to support a mature theater. These units must be self-sustaining for a period of time, able to operate as part of a multifunctional organization, and 100 percent mobile using organic assets. Training for combat operations and SASO is an essential element of readiness, effectiveness, and success.

2-5. The mission of ammunition support units is to provide the required type and amount of ammunition to the combat user at the needed time and location. Therefore, ammunition units are organized and deployed to meet mission support requirements. In peacetime, they operate out of fixed sites with all associated support and facilities in place. When deployed, they operate in an unfriendly or hostile environment to support a combat force. The condition of facilities may be uncertain, and operational support may be unstable for an undetermined period.

2-6. Since there is no one scenario for combat operations/SASO, ammunition units must be prepared to support operations ranging from peacekeeping to regional conflicts to major war. Like other logistical support, ammunition support requires that the unit have the appropriate mix of personnel, MOS skills, and tools and equipment to accomplish the mission.

CLASS V SUPPORT OPERATIONS

2-7. A review of US Army involvement in recent operations clearly indicates the need to improve logistical planning. Plans must be developed to support all levels of combat operations/SASO. It is critical that Class V support planning be detailed and threat-based. See FM 100-5 for discussions covering the following:

- Five tenets of Army operations doctrine.
- Five logistics characteristics essential to supporting combined arms operations.
- Four support considerations for incorporating sustainment imperatives into support planning.

Ammunition units will apply this guidance when developing plans to support ASCC or CINC plans and priorities.

2-8. Ammunition support planners must stay ahead of the situation as operational campaigns unfold by reinforcing successes with priority of support, planning for forward logistics bases, and extending lines of support. As tactical developments render earlier support plans obsolete, ammunition support planners formulate new ones. For more information on CSS, see FM 100-10.

2-9. Because units must deploy quickly, they do not have time for detailed, last minute planning. For example, when a unit deploys to a maturing theater, a support infrastructure may not be available to provide the logistical information needed to perform the mission. The unit commander must identify the logistical support structure that will sustain the unit. This type of contingency planning must be done in peacetime so that the unit can develop detailed SOPs and plans. At a minimum, the following factors must be considered during planning:

- Local POCs for unit support (i.e., computer, engineer, signal, security, defense, transportation, and POL).
- Status charts for unit personnel, equipment, and ammunition, including organic basic load (see Appendix A).
- Replacements for equipment, personnel, ASL, and PLL.
- Factors affecting the mission (i.e., stock objectives; chain of command; site locations/grid coordinates of supported units; identifying supporting MMC and MCCs, and QASAS; and HAZMAT certified personnel).
- Equipment staging location and procedures.
- Organization of march units.
- Organization of duties for advance and rear parties and reconnaissance element.
- Densities and speeds for different types of moves.
- Maintenance of records, including ammunition accountability and serviceability.
- C2 procedures.
- Actions to take in the event of attack.
- Accident and maintenance procedures.
- Messing and refueling procedures.
- Communications methods.
- Load plans for personnel, equipment, and ammunition-related materiel.
- Night operations.
- Continuity of operations plan.
- Directional signs, fire symbols, and FSU stack signs sufficient for three storage locations.
- Retrograde operations.
- Identification of QASAS source organization and method of acquiring support.

Less complex local and field SOPs will be developed as necessary. For more information, refer to FM 100-5.

STANDING OPERATING PROCEDURES

2-10. Field SOPs of ammunition units are based on logistical field SOPs of the command organizational element. They provide guidance in developing SOPs for supported units to facilitate the ammunition support process. SOPs must be adapted to actual operational conditions. Regardless of the SOP being written, considering worst-case situations is the key to useful, effective planning. At a minimum, external SOPs must cover the following:

- Unit and Class V WHNS.
- Communications, engineer, and transportation support.
- Safety.
- Ammunition issue and turn-in procedures.
- Protecting ammunition from the elements.

- Emergency resupply procedures.

At a minimum, internal SOPs must cover the following:

- Deployment (i.e., staging) procedures.
- Field setup, including storage, perimeter defense, and storage facility layout plans.
- Operational procedures, including ammunition receipt, storage, issue, and maintenance operations.
- Link to C2 element.
- Routine and emergency destruction plans.
- Fire-protection plans and other safety concerns.
- Air resupply procedures.
- Logistical plans for required augmentation elements (e.g., QASAS personnel).

During actual combat operations or SASO, there is no time to develop plans and procedures. Development of simple, realistic SOPs are essential for fulfillment of the unit Class V mission.

PREPACKING

2-11. To make any plan work in the changing combat/SASO environment, everything possible must be done in advance. Prepacking is one of the most useful actions a deploying unit can take. While expendable supplies are generally available through normal supply channels, a period is likely when these items may not be obtainable. Units must prepack as many expendable supplies as possible (e.g., blank forms, directional signs, ammunition placards, banding, paint, and stencils) that can be packaged and/or palletized for transport. Consideration must be given to developing packing lists that cover a variety of METT-TC environments.

2-12. Another critical asset to prepack is a complete, up-to-date Class V reference library that also includes applicable transportation publications. Commanders must ensure that manuals required to complete support tasks and maintain organic equipment are included in packing preparations.

TRANSPORTATION

2-13. MOADS-PLS ammunition companies are only 50 percent mobile, less ammunition stocks. Because they do not have sufficient organic transportation to move an entire unit at one time, additional transportation must be requested. Transportation requests are normally coordinated through the unit C2 element to the nearest MCT and/or local transportation activity. For information on motor transportation request procedures, see FM 55-10. Transportation requests will include the following information:

- Move date.
- Routes.
- Destination.
- Time and place transportation required.
- Number of personnel to be moved.

- Quantity, type, weight, and cube of cargo.

Although modular ammunition platoons are 100 percent mobile minus ammunition stocks, they must still coordinate unit movements through their supporting higher headquarters.

RETROGRADE

2-14. Upon completion of combat operations or SASO, the ammunition retrograde process begins. This process includes the following steps:

- Collecting.
- Identifying.
- Inspecting.
- Requesting disposition instructions.
- Repackaging.
- Load planning.
- Shipping.

Retrograde of ammunition generally includes the return of unserviceable ammunition, CEA, and serviceable ammunition to rear supply or depot facilities.

2-15. In recent operations, excessive amounts of munitions were requisitioned and issued to deploying forces, placing a tremendous burden on the ammunition support system. The high cost and low density of current and emerging technology munitions mandate the planning and development of a system for retrograde operations that begins at the onset of combat operations or SASO. The functions of estimating and monitoring the amount of repackaging materials needed for the retrograde of munitions are critical. Requisitioning these materials at the last minute may be difficult, particularly during redeployment when competition for movement of all types of materials is intense. Retrograde operations must be covered in field SOPs, and strong emphasis given to return of packaging materials by using units.

TRANSITION TO COMBAT/SASO

2-16. The transition from a peacetime mission and the move from an installation, post, camp, or activity are major steps for ammunition units. Commanders must ensure that officers and NCOs understand the transition process, and that unit training is given priority. This understanding and training prepare the unit to deploy to its assigned area and perform its mission effectively and efficiently.

2-17. During movement, units must continue to execute contingency plans and tactical operations. When a move is to be made, the following must be considered:

- Planning.
- Equipment and personnel.
- Transportation.
- Reconnaissance and site selection.
- Area preparation and layout.

- Defense, security, and area damage control.

2-18. Command elements analyze many factors when making decisions concerning unit deployment. These factors include the following:

- Location or theater of deployment.
- Operational situation (i.e., forced or permissive entry).
- Date and time of deployment.
- Support structure in theater.

2-19. Many deployment decisions are made based on answers to critical questions. Questions that must be addressed prior to deployment include the following:

- Will the deployment be as a unit, and will advance, main, and rear parties be required?
- Will the deployment be in phases?
- What organization will act as the POC in the theater?
- What is the deployment mission (i.e., forward in support of a brigade-, corps-, or division-size force)?
- What is the theater situation?

2-20. The warning order for deployment normally includes the general location of the area in which the unit will conduct its operations, the movement date, and a list of special requirements or instructions. When notified of an impending move, the unit commander alerts unit personnel and initiates planning. The move is coordinated with the supporting C2 element and transportation activity. The commander determines the type of move to be made (unless specified), requests additional transportation as necessary, takes steps to phase out current operations, and schedules a reconnaissance of the area.

2-21. Rapid, efficient deployments are subject to the detailed contingency planning and preparation of simplified field SOPs discussed earlier. To ensure a successful move under stressful conditions, unit training must employ these contingency plans and SOPs, making adjustments as necessary, until procedures are understood thoroughly by all unit personnel. See Appendix B for guidance that commanders can use in preparing for deployment. There likely will be a continuing need to forecast and manage training ammunition effectively. See Appendix C for information and guidance.

POST-COMBAT/SASO TRANSITION

2-22. One of the major missions of all ammunition support units, following completion of combat operations/SASO, is the retrograde of Class V materiel and components. Retrograde operations often signal the beginning of the redeployment process (see earlier discussion on retrograde operations). The same amount of detail given to transitioning to combat operations/SASO should be given to redeployment operations. Post-combat/SASO transitions may constantly change. Unit commanders must maintain close coordination and contact with their C2 element to ensure that their unit's deployment is carried out as smoothly as possible. Briefings should be conducted frequently to control rumors and prevent erroneous information from having a negative effect on morale and operations.

2-23. Command emphasis must be given to training for transition to and from combat operations/SASO. Scenario-based training is often the most effective method since preplanning and transitions can be emphasized separately. A unit's ability to develop situational SOPs may be somewhat dependent on logistical guidance from their C2 element and higher logistical headquarters. However, it is always appropriate to maintain a standard SOP package that can be tailored to meet operational requirements. Preplanning and training can ease the strain and stress characteristic of deployment, unit movement, and redeployment.

SUMMARY

2-24. Combat operations and stability and support operations require detailed munitions support planning consistent with the Army's doctrine, logistic characteristics, and support considerations. Support planners must adapt quickly to changing requirements as a result of tactical successes. Combat/SASO and post-combat/SASO transitions are major missions of munitions units.

Chapter 3

Munitions Supply Procedures

This chapter describes combat/SASO ammunition supply operations. These operations include receipt, turn-in, issue, shipment, and retrograde.

RECEIPT

3-1. The term, *receipt*, refers to a shipment of ammunition received from an ASP, a CSA, or a TSA, or directly from a port, depot, or manufacturing plant. Receipt must not be confused with unit turn-in. Ammunition receipt operations include completion of administrative details, inspection of vehicles, and unloading of ammunition at the designated storage location. Stocks received by an ammunition supply unit are recorded on stock records, reported to the appropriate MMC, and stored for subsequent shipment or issue.

3-2. The supporting MMC normally notifies an ammunition unit in advance of a scheduled incoming shipment. However, unscheduled emergency resupply shipments may arrive at any time. To ensure that notification is received, the unit should maintain close coordination and communication with the MMC. Once the unit receives a notice, it selects storage locations and makes plans to unload and store the ammunition. During the planning stage, the unit must examine storage compatibility, Q-D requirements, and security factors. Also, it must consider any mission requirements for configuring stocks into MCLs. It may be necessary to rewarehouse or consolidate some stocks already in storage to make room for additional stocks and to facilitate vehicle off-loading at the planned storage location. Planning also includes assigning enough people and equipment to complete the operation safely and efficiently.

3-3. Receipts at TSAs and CSAs are normally in large quantities. TSAs receive 100 percent of stocks directly from the POD, and CSAs receive 50 percent from the POD and 50 percent from the TSA. Receipts may arrive on trailers or PLS flatracks in palletized break-bulk configuration or in containers. It is also possible that some will arrive as configured loads. In a mature theater, representatives of ammunition units may be tasked to assist with the off-loading and distribution of stocks at the POD. In an immature or maturing theater, an LSE or AST coordinates off-loading and distribution of stocks to storage areas. See FM 9-6 for more information.

3-4. When the shipment arrives at the storage location, the convoy commander or supervisor provides the control section with a copy of the shipping/receipt documentation. Vehicles are inspected in the vehicle holding area before entering the ammunition storage area.

GUIDELINES

3-5. Attention to the following guidelines makes the receipt of ammunition safer and easier to control:

- Be aware that a single shipment may contain mixed DODICs, NSNs, and lot numbers. Conduct a detailed inventory during or after the unloading process. Use advanced notices of receipts for planning storage location operations.
- Inspect ammunition thoroughly for damage and safety hazards.
- Check unit SOP for guidance if ammunition is arriving by a particular mode of transportation.
- Check planographs, magazine drawings, or FSU sizes to determine if rewarehousing is needed to accommodate the receipt. Complete rewarehousing before shipment arrives.
- Consider the amount of labor, MHE/CHE, and time required for off-loading.

DOCUMENTATION

3-6. The forms listed below are generally required when receiving ammunition. An "R" following the form number indicates that the unit may reproduce the form.

- DA Form 3020-R. Prepared for each lot and stack of ammunition stored during receiving operations.
- DA Form 3151-R. Used to record storage locations of all items in the shipment.
- DD Form 626. Used by storage facility personnel to inspect arriving vehicles before unloading. Prepared IAW 49 CFR and DOD Regulation 4500.9-R.
- DD Form 1348-1A. Prepared by the shipper, an accountable document used to complete the shipment. Contains detailed information about the shipment.
- DD Form 1384. Prepared by shipper, provides vital data concerning the shipment. Stays with ammunition during shipment.

PROCEDURES

3-7. The flowchart in Figure 3-1 is a guide for planning and conducting receiving operations at the ASA based upon a receipt of notification from the MMC. It can also be used for writing SOPs for ammunition receipts.

TRANSPORT INSPECTION

3-8. Military ammunition inspectors, QASAS, or other qualified personnel inspect all incoming, loaded transports before they enter the storage area, regardless of the transportation mode. Since ammunition is especially sensitive to fire, the transports (e.g., tractors, trailers, railcars) and their cargo must be inspected for safety and fire hazards. Also, inspectors must check the transports for evidence of tampering or sabotage. Inspectors will inform the driver or convoy commander of any deficiencies. If the deficiencies cannot be corrected, the driver or convoy commander will coordinate with his unit to ensure that serviceable transports are provided.

○ MMC
● Shipper
■ Convoy CMDR Driver
▲ ASA Office
⊗ Checker
⊕ Inspector

No	Activity	Document	○	●	■	▲	⊗	⊕
1	Initiate Shipment	DD 1348-1A	○					
2	Provide Advanced Notice to Receiver	DD 1348-1A		●				
3	Conduct Advanced Planning for Receipt					▲		
4	Ship Ammunition	DD 1384 DD 1348-1A		●				
5	Arrive at ASA				■			
6	Inspect Vehicles Prior to Entry	DD 626						⊕
7	Correct Deficiencies - if Noted	DD 626			■			
8	Park Loaded Vehicles in Holding Area				■			
9	Present Documentation to ASA Office	DD 1384 DD 1348-1A			■			
10	Review Documentation	DD 1348-1A DD 1384				▲		
11	Select Storage Locations	PLANOGRAPH				▲		
12	Prepare Stores Slip for each Vehicle	DA 3151-R				▲		
13	Prepare Magazine Data Card for Each Lot/Location	DA 3020-R					⊗	
14	Assign Checkers, Unloading Crews, MHE					▲		
15	Give Stores Slips and Mag Data Cards to Checkers					▲		
16	Escort Vehicles to Storage Locations				■		⊗	
17	Verify Type, Lot, Condition, Quantity Received	DA 3151-R			■		⊗	⊕
18	Sign Stores Slip	DA 3151-R			■		⊗	
19	Annotate Magazine Data Card						⊗	
20	Conduct Receipt Inspection							⊕
21	Drive Empty Vehicles to Assembly Area				■			
22	Return Stores Slip to ASA Office	DA 3151-R					⊗	
23	Verify Stores Slips for Accuracy and Completeness	DA 3151-R				▲		
24	Total Stores Slips by Lot and Location	DA 3151-R				▲		
25	Review Suspension File for Lots Received					▲		⊕
26	Cross Check Stores Slip With Receipt Documents	DA 3151-R DD 1348-1A, 1384				▲		

Figure 3-1. Receipt Procedures

27	Recheck Actual Receipts - if Discrepancy Noted	
28	Record Actual Receipts on Receipt Documents	DD 1348-1A DD 1384
29	Sign Receipt Documents	DD 1348-1A DD 1384
30	Depart ASA With Signed TCMD	DD 1384
31	Post Lot Locator Records	SAAS
32	Forward Materiel Receipt Transaction to Supporting MMC	SAAS
33	Record and File Documentation	ALL

Figure 3-1. Receipt Procedures (Continued)

Motor Vehicles

3-9. Motor vehicles are inspected as they arrive at the storage facility using DD Form 626, which is carried with each shipment. The driver must have a valid vehicle operating permit and HAZMAT qualification unless exempted by an HN agreement. Also, the following items on the vehicle will be inspected:

- Cargo area for excessive debris and POL products.
- Steering for safe operation.
- Windshield and wipers for adequate operation.
- Fire extinguishers for serviceability.
- Brakes and lights (especially for night operations) for proper operation.
- Exhaust system for accumulation of grease, oil, or gasoline and carbon monoxide fumes leaking into the cab.
- Fuel tanks and lines for leaks.
- Trailer coupling device for serviceability.
- Tires for any dangerous condition.
- Ammunition load to ensure it is securely blocked and braced or secured with cargo straps.

Under no circumstances will a vehicle be allowed into an ASA with a defect that endangers the load or the ASA.

Railcars

3-10. In most cases, a QASAS is available when the railcar is spotted and opened. Inspections are conducted at a designated inspection area. If sabotage or other unsafe condition is suspected, the railcar will be moved to another area so that authorized security and/or EOD personnel can inspect it. Off-loading can begin as soon as the car passes inspection.

Aircraft and Vessels

3-11. The assistance of other services is necessary to ensure that aircraft and vessels are inspected properly. Also, a QASAS/qualified military inspector must be available at the storage area since transporting with aircraft and vessels requires motor vehicles or railcars to move munitions to and from the actual storage site.

3-12. Transport inspections ensure that the mission can be completed with minimal danger to personnel and that there will be no loss of munitions due to unsafe conditions. Peacetime inspection criteria are stringent. While criteria or standards may be relaxed to speed the flow of ammunition during combat/SASO, it must not be enough to cause unwarranted safety hazards. Unit commanders must ensure that any relaxation of the inspection policy is fully understood by ammunition unit personnel and that safety standards are clarified to using units. See DA Pam 385-64 for added guidance.

STORAGE PROCESS

3-13. The control section initiates the storage process when it reviews receipt documentation, selects storage locations, and prepares a DA Form 3151-R. Checkers and other personnel and equipment are assigned to off-load the vehicles. Checkers escort vehicles or group of vehicles to the storage locations where type, lot, condition, and quantity of load are verified and inspections are conducted. As ammunition is stored, the checker/storage personnel will either prepare a DA Form 3020-R for each lot number by condition code and location or update the existing form.

3-14. After each motor vehicle is off-loaded, it is driven to the vehicle assembly area and returned to the control of the convoy commander. The checker returns the DA Form 3151-R to the control section where it is reviewed for accuracy and completeness. The total quantity of each item as shown on the DA Form 3151-R is cross-checked against the total quantity shown on the shipping/receipt document. The accountable officer signs the shipping/receipt document, and posts accountable stock records. A signed copy of this document is given to the convoy commander or supervisor. All transaction documents are filed for use as backup for posting accountable records.

3-15. If a discrepancy is noted between the two transaction documents, a recount is made. The actual quantity verified as received by the control section is entered on the shipping/receipt document. Discrepancies in quantity or condition of ammunition are reported to the shipper using an SF 364, Report of Discrepancy.

3-16. Depending on the storage facility, some modification of the process in Figure 3-1 may be necessary. However, any modification will be based on maintaining flexibility, simplicity, and adequate control during receipt operations. See Chapter 9 for more information on the storage process.

TURN-INS

3-17. The term, *turn-in*, refers to the return of unexpended ammunition and salvage items to a storage facility by the using unit. Turn-ins must not be confused with receipts. During combat/SASO, the quantity of turn-ins is difficult to predict and depends on mission requirements, redeployment schedules, and a variety of other factors. Turn-ins may include unserviceable items, unused ammunition, and CEA. Regardless of the quantity or rate, all items must be thoroughly inspected and reported to the control section. For safety and economy, commands must encourage units to return munitions in original packaging. Ammunition support units must develop an SOP that outlines operations and procedures for returning ammunition and residue. See AR 710-2 and DA Pam 710-2-1 for more information.

3-18. Using units may be required to turn in salvage and residue materiel, including expended cartridge cases, containers, wooden boxes, and metal cans. To ensure that explosive items are not mixed in, all such materiel must be thoroughly inspected. Salvage materiel is stored in the inert salvage area. It is inventoried, recorded, and reported to the appropriate MMC for disposition instructions. The accountable officer must ensure that required documents are maintained.

GUIDELINES

3-19. For safer and easier control of the munitions turn-in process, the following guidelines must be observed:

- Encourage units to return munitions in original packaging.
- Discourage units from opening more rounds and packages than they need for their operations.
- Inspect all turn-ins thoroughly to identify unserviceable and hazardous munitions and mixed lots.
- Inspect all salvage and residue items thoroughly to ensure that they do not contain any explosive or hazardous materials.

The above points must be emphasized throughout the logistic and combat chains. Emphasis is more stringent in SASO where using units must exercise greater control. Also, the potential exists for operations to be concluded without expenditure of munitions. The greater the control, the smoother and more economical the retrograde/redeployment process. Munitions managers at the unit, brigade, division, corps, and MMC levels must be consistent in the guidance they provide.

DOCUMENTATION

3-20. The forms listed below are used for processing turn-ins. An "*R*" following the form number indicates that the unit may reproduce the form.

- DA Form 581. Prepared by using unit for turn-in of munitions and munitions-related items. Presented to storage facility at arrival.
- DA Form 581-1. Used by unit when number of DODICs requested is more than can fit on the DA Form 581.
- DA Form 3020-R. Prepared by storage facility for each lot and stack of munitions turned in. Checkers post transactions to existing form and ensure it is completed accurately.

- DA Form 3151-R. Prepared by storage facility as temporary receipt or storage document. Directs relocation of specific items to specific storage locations. Used to track the movement of munitions within the storage facility.
- DD Form 626. Used by storage facility to inspect vehicles for hazardous conditions before they enter the storage area.

PROCEDURES

3-21. The flowchart in Figure 3-2 helps in planning for and efficiently conducting receipt of using unit turn-ins. Also, it may be helpful for writing SOPs. Depending on the storage facility, some modification of this process may be necessary. Salvage and munitions turn-ins are handled in much the same way with the following exceptions:

- Salvage materiel must be inspected for hazardous materials and certified that none are present.
- Salvage materiel is stored in an area separate from munitions.
- Salvage turn-ins must also be accounted for on stock records.
- Small arms residue is not individually counted; its weight is converted to rounds using brass conversion factors (see Appendix D).

Salvage and recoverable items are listed in DA Pam 710-2-1, Appendix J. Within the theater, the MMC may direct the recovery of additional salvage materiel.

ISSUES

3-22. The term, *issue*, refers to the transfer of ammunition stocks from a munitions storage facility to an authorized user, but not to another storage facility. Issues should not be confused with shipments. Units use the supply point distribution method to issue ammunition to using units. Responsible activity managers must support mission requirements. However, they must do so IAW guidance provided by higher headquarters relative to munitions support of using units in the AO. This process must be established as early as possible and understood by ammunition support units and using units. The OPORD logistical support annex and SOPs are developed to define issue operations and procedures.

3-23. Issues are based on S3 identified munitions requirements processed from the using unit's battalion S4 up to the brigade S4. The brigade S4 consolidates munitions requests and forwards them to the supporting FSB and to the DAO. The DAO coordinates with the corps MMC to meet unit ammunition requirements. Also, the brigade S4 and the DAO monitor the CSR, critical item shortages, and unit priority for munitions resupply. The CMMC supports these requirements by sending an MRO to the appropriate ammunition storage or supply activity.

○ Using Unit
● DAO
■ Convoy CMDR/Driver
▲ ASA Office
⊗ Checker
⊕ Inspector
□ INV Control

No	Activity	Document	○	●	■	▲	⊗	⊕	□
1	Prepare Turn-In Request	DA 581	○						
2	Approve Turn-In	DA 581		●					
3	Transport Ammunition to ASA	DA 581	○		■				
4	Arrive at ASA		○		■				
5	Inspect Vehicles Prior to Entry	DD 626						⊕	
6	Park Loaded Vehicles Prior to Entry				■				
7	Present Turn-In Documentation to ASA Office	DA 581	○						
8	Review Documentation	DA 581				▲			
9	Coordinate Checkers, MHE, and Inspectors					▲			
10	Escort Vehicles to Segregation Area		○		■		⊗		
11	Unload, Segregate by DODIC and Lot		○		■		⊗		
12	Prepare Temporary Receipt	DA 3151-R					⊗		
13	Drive Empty Vehicles to Assembly Area				■				
14	Return Temporary Receipt to ASA Office	DA 3151-R					⊗		
15	Total All Stores Slips	DA 3151-R				▲			
16	Fill In Turn-In Document With Quantity	DA 581				▲			
17	Receipt Signature	DA 581	○			▲			
18	Return to Unit	DA 581	○		■				
19	Conduct Detailed Inspection of Items Received							⊕	
20	Assign Condition Codes							⊕	
21	Review Suspension File for Lots Received							⊕	
22	Notify ASA Office of Inspection Results	DA 3151-R						⊕	

Figure 3-2. Turn-In Procedures

23	Select Storage Locations	
24	Prepare Stores Slips and Magazine Data Cards	DA 3151-R
25	Assign Checkers, MHE, and Crews	
26	Relocate Turn-Ins to Storage Locations	DA 3151-R
27	Fill Out Stores Slips, Magazine Data Card	DA 3151-R DA 3020-R
28	Return Stores Slips to ASA Office	DA 3151-R
29	Verify Stores Slips for Accuracy	DA 3151-R
30	Post Lot Locator Records	SAAS
31	Report Unserviceable Munitions to the MMC	DA 2415
32	Report Turn-In on Daily Transaction Report	
33	Record and File Documentation	All

Figure 3-2. Turn-In Procedures (Continued)

GUIDELINES

3-24. The following guidelines will assist ammunition units in providing efficient support:

- Issue only serviceable munitions. See Appendix E for Ammunition Condition Codes.
- Advise using units about limitations on the use of restricted munitions and munitions suspended from issue and use except for emergency combat. Depending on the type of operation, some munitions may not be authorized for issue, even if they are available at the storage facility. Ammunition units must ensure that any policy regarding such specific items is clearly understood. The supporting MMC is a good source of information.
- Never issue munitions classified as "*suspended from issue and use*."
- Closely monitor issues of miscellaneous small lots of artillery munitions so that using units do not constantly have to adjust registration.

3-25. Munitions must be issued as follows:

- *Priority 1.* Smallest lots of munitions issued first.
- *Priority 2.* Munitions designated as "priority issue."
- *Priority 3.* Acceptable substitutes from excess stocks. Coordinate approval of substitution with requesting officer.
- *Priority 4.* Oldest munitions of type being issued.
- *Priority 5.* All other stocks.

DOCUMENTATION

3-26. The forms listed below are needed to issue munitions. An "R" following the form number indicates that the unit may reproduce the form.

- DA Form 581. Prepared by the requesting unit and presented to the storage facility for issue.
- DA Form 1687. Properly completed form presented to storage facility by using unit. Used to ensure that DA Form 581s have the proper signatures.
- DA Form 3020-R. Prepared by storage facility for all munitions in storage. Checkers post transactions affecting the on-hand balance to the existing DA Form 3020-R and ensure that forms are accurately completed.
- DA Form 3151-R. Prepared by storage facility as a temporary receipt or storage document. Directs the relocation of specific items to specific storage locations. Used to track movement of munitions within the storage facility.
- DD Form 626. Used by storage facility to inspect vehicles for hazardous conditions before they enter storage area.
- DD Form 836. Prepared by storage facility for each driver of a vehicle that leaves the facility loaded with munitions. Drivers must keep this form in their possession *at all times* while transporting munitions.

PROCEDURES

3-27. As stated above, the DA Form 1687 is used to ensure that DA Form 581 has the proper signatures. In a division, the DAO or designated representative authenticates the DA Form 581 or facsimile-formatted document before the requesting unit arrives at the storage facility. In corps artillery, the S4 officer may be designated to authenticate the request. Authentication gives tactical commanders control of ammunition issues. With proper controls, ammunition managers at all levels can comply with sudden changes in priorities and allocations of munitions assets.

3-28. Combat operations/SASO and mission requirements are subject to constant change. Based on a last-minute change, for example, the using unit may arrive at the issue facility with a verbal request to change the quantity or type of items to be issued. The ASA, in coordination with the DAO or other command representative and the MMC, must then determine whether stocks are sufficient to support the requirement. All responsible parties will verify the issue. The ammunition unit SOP must contain guidelines to cover such situations.

3-29. Each storage facility maintains a list of the units it supports. While a basic list should be available from the supporting MMC or DAO, operational considerations may cause the list to evolve constantly. The storage facility must coordinate closely with the MMC to maintain mission continuity and to identify theater-specific policies that differ from the policies used by ammunition units in ordinary circumstances. The flowchart in Figure 3-3 is a guide for planning and conducting efficient issue operations. It may also be used for writing SOPs for munitions issues.

○ Using Unit
● DAO
■ Convoy CMDR Driver
▲ ASA Office
⊗ Checker
⊕ Inspector
□ MMC

No	Activity	Document	○	●	■	▲	⊗	⊕	□
1	Prepare Request	DA 581	○						
2	Authenticate Request	DA 581		●					
3	Travel to ASA--Park in Vehicle Holding Area		○		■				
4	Present Request to ASA Office	DA 581	○						
5	Review Request for Accuracy, Completeness, and Proper Authentication	DA 1687				▲			
6	Inspect Empty Vehicles	DD626						⊕	
7	Select Lots and Storage Locations	DA 5203				▲			
8	Prepare Issue Stores Slip	DA 3151-R				▲			
9	Review Suspension File With Lot Selected	DA 3151-R						⊕	
10	Review DSR Cards for Inspection/Condition	DA 3022-R						⊕	
11	Verify Condition of Lots Selected for Issue	DA 3151-R						⊕	
12	Assign Checkers, Loading Crews, MHE					▲			
13	Distribute Stores Slip	DA 3151-R				▲			
	a. Original to Checker	DA 3151-R					⊗		
	b. Copy With Suspense Request	DA 3151-R				▲			
14	Escort Vehicles to Storage Locations		○		■		⊗		
15	Load, Block, Brace, and Inventory Vehicle	DA 3151-R	○		■		⊗		
16	Sign Stores Slip Jointly	DA 3151-R	○				⊗		
17	Fill Out Magazine Data Card	DA 3020-R					⊗		
18	Drive Loaded Vehicles to Assembly Area				■				
19	Inspect Loaded Vehicles	DD 626 DD 836						⊕	
20	Return Stores Slip to ASA Office	DA 3151-R					⊗		
21	Verify Original Stores Slip With Suspense Copy	DA 3151-R				▲			
22	Total All Stores Slips	DA 3151-R				▲			
23	Enter Total Quantity Issued	DA 581				▲			
24	Get Receipt Signature	DA 581				▲			
25	Distribute Documentation	DA 581 DA 3151-R				▲			
26	Return to Unit	DA 581 DD 626, 836	○		■				
27	Post Records	SAAS	○	●	■	▲		⊕	
28	Report Issue on Transaction Report	SAAS				▲			
29	Process Transaction and Initiate Any Necessary Resupply								□

Figure 3-3. Issue Procedures

004159

SHIPMENTS

3-30. The term, *shipment*, indicates the movement and transfer of ammunition stocks from one storage facility to another–either into, within, or out of the theater. It includes movement to an ATP using transportation assets not organic to ammunition units. Also, it includes retrograde of serviceable and unserviceable munitions and CEA to the theater rear or out of the theater. Normally, theater, corps, or HN transportation assets are used for transportation. Shipments are not to be confused with issues.

3-31. In routine operations, ammunition shipments between storage facilities are directed by MRO only from the supporting theater or corps MMC. These shipments are made up from operating stocks arriving in the theater or from those stored in the TSAs or CSAs. Shipments over and above established CSR constraints may be made provided the theater Class V stock level exceeds theater demand and if approved through higher command channels. Shipments out of the theater to support other contingencies may also be made when directed. The DAO determines the munitions status of the division ATPs and decides if munitions in the division can be cross-leveled to meet division requirements.

3-32. In most situations, shipments in the combat/SASO zone are limited to highway transport. The MCA schedules transportation according to theater or corps priorities. Rail and water facilities may be used when available and if feasible. Aircraft are used only when absolutely necessary, usually for emergency resupply or special operations.

3-33. Munitions shipments to TSAs and CSAs are mostly containerized or palletized in break-bulk and uploaded on trailers or PLS flatracks. In most cases, only containerized munitions arrive at the TSA/CSA where they are unstuffed, configured into MCLs, and shipped forward to ASPs. If the mission requires, and if transportation is available, munitions are throughput as close to the using units as possible.

3-34. Munitions shipped from CSAs to ASPs are either in MCLs or break-bulk/single DODIC loads on PLS flatracks. ATP shipments from the CSA and the ASP are either in MCLs, break-bulk, or single DODIC loads. See FM 9-6 for more information on munitions flow in the theater of operations.

GUIDELINES

3-35. The supply facility begins planning the mechanics of the specific shipment upon receipt of an MRO, shipping instructions, or other shipment authority. The thoroughness of advance planning largely determines the efficiency of any shipping operation. Plans vary depending on the tactical situation, operational environment (i.e., METT-TC), type of shipment, and existing workload. Most accidents involving Class V items occur during transportation, movement, and handling. A detailed, step-by-step SOP will make shipment activities safer and more effective. The following actions must be considered when planning a shipment:

- Verify availability of ammunition for shipment against on-hand assets.
- Select adequate loading points for the operation.

- Verify the condition code and any restrictions or suspension of the ammunition planned for shipment.
- Determine total gross weight, cube, and security risk classification of the ammunition.
- Determine ammunition compatibility for transportation IAW applicable motor vehicle/rail compatibility tables.
- Coordinate with supporting MMC to ensure advance notice of munitions shipments.
- Determine personnel necessary to complete the mission.
- Determine MHE required.
- Determine safety equipment, tools, packaging, and blocking and bracing materials required.
- Establish timeline for entire operation.
- Determine vehicle load plans and placarding requirements prior to start of operation.
- Ensure security of munitions throughout entire operation.

3-36. The responsible MCC maintains liaison with local transportation agencies and designates an MCT to be the single point of contact for each shipping or receiving activity. The MCT is the link between the shipping activity and the transportation service organization. It receives transportation service requirements from the MCC and processes the requests. The MCT coordinates the activities of transportation operators and expedites movements of incoming and outgoing carriers.

3-37. The ammunition unit must coordinate with the MCT to ensure efficient transportation and ammunition service support. The unit must provide timely, accurate data on pending shipments. This way, the MCT can supply advance information on the mode of transportation, the time of arrival, and the positioning (spotting) of carriers.

3-38. The MCT notifies the receiving activity of the departure time, estimated time of arrival, transportation mode and number of transportation units involved, and other information needed to plan for receipt. Supporting transportation agencies should provide an SOP based on the policies and directives of the higher headquarters.

SHIPPING REGULATIONS

3-39. Ammunition shipments within a theater of operations must comply with theater and DA directives, safety regulations, and HN requirements (METT-TC-dependent). These directives may or may not be compatible with those used in CONUS. See DOD 4500.9-R for more information on shipments of ammunition. ARs 55-38, 710-2, 735-5 and 735-11-2 contain information on using required transportation documents.

TRANSPORT INSPECTION

3-40. Military ammunition inspectors, QASAS, or other qualified personnel will inspect vehicles as discussed in the Receipts section of this chapter.

TRAILER/TERMINAL TRANSFER POINTS

3-41. A TTP is a point on the route between the origin of supplies and the destination where supplies are transferred from one means of transport to another (e.g., transfer of Class V supplies from railcar to cargo truck or from cargo truck to aircraft). Normally, TTPs are the responsibility of transporters. However, when Class V items are involved, transportation personnel may require technical advice and assistance from ammunition unit personnel. TTPs should not be confused with ATPs.

RAIL SHIPMENTS

3-42. Railhead operations, US/WHNS, may be part of ammunition supply operations. A railhead is a transfer point where ammunition is moved from truck to railcar, or vice versa. Specific guidance for shipping by rail—including safety precautions, loading, blocking and bracing, positioning (spotting) of loaded cars, certifying cars, and inspecting loads—are found in DA Pam 385-64; CFR, Title 49; and if available, AMC drawings. Inspection standards during combat operations/SASO are based on theater policy, METT-TC, and criticality of mission.

WATERBORNE VESSEL SHIPMENTS

3-43. While ammunition supply units may be required to provide technical assistance, MTMC and transportation units are responsible for loading and off-loading waterborne vessels in the theater of operations. See DA Pam 385-64 and CFR, Title 49 for more information. Also, USCG regulations govern the classification, compatibility, and stowage of ammunition aboard all waterborne vessels in waters under US jurisdiction. The Coast Guard is usually responsible for the security and supervision of waterborne vessels, including barges.

MOTOR VEHICLE SHIPMENTS

3-44. All ammunition supply facilities use motor vehicle procedures for shipping operations. DD Form 1384 or a facsimile formatted document may be used to request transportation for a shipment. Requirements may be coordinated via computer, telephone, or radio links. See DA Pam 385-64 for motor vehicle shipment regulations, precautions and safe handling procedures, inspection criteria, and technical escort procedures. Shipper and carrier responsibilities are contained in DOD 4500.9-R and theater-specific transportation regulations.

AIR SHIPMENTS

3-45. Air shipments of ammunition may be made at USA and USAF airfields, at heliports, and at ammunition sling-load areas. The Air Force controls air terminal operations at USAF airfields. Munitions shipments into and out of USAF facilities require careful coordination to prevent disruption of service.

Airfields must have staging areas where documents may be prepared and bulk shipments can be received and prepared for shipment.

3-46. Air shipments are preplanned for each aircraft by weight, cube, and compatibility. When possible, the arrival of loaded vehicles will coincide with aircraft availability. Normally, Army/Air Force personnel escort vehicles to the aircraft. The aircraft commander, loadmaster, or crew chief is responsible for supervising the stacking and lashing of the cargo.

3-47. The Class V storage facility is usually responsible for sling-load areas. Loaded cargo nets must be placed in the landing area so that helicopters can hover to pick them up. Cargo nets may be loaded at the airfield or at the ammunition supply facility and transported to the airfield.

3-48. A Hazardous Materials Declaration, or facsimile-formatted document, must be attached to each pallet of ammunition to be shipped by military or commercial aircraft. This document certifies that the shipment complies with the provisions of TM 38-250 or 49 CFR. An individual who has successfully completed the Special Handling Data/Certification Course must sign all copies of the form. For information on aircraft specifications, operating regulations, loading and unloading procedures, and special handling certification, see AR 95-27, DA Pam 385-64, TM 38-250, and 49 CFR.

DOCUMENTATION

3-49. The forms listed below are needed to ship ammunition. An “R” following the form number indicates that the unit may reproduce the form.

- DD Form 1384. Prime transportation information document prepared for each shipment by the supply activity making the shipment; carries transportation data throughout the movement cycle. Basis for advance planning; speeds movement of cargo at terminals and other transshipment and transfer points. Provides information needed to trace, locate, and divert shipments. During combat/SASO, a facsimile-formatted document prepared manually, by computer, or in message format may be used.
- DD Form 626. Used by storage facility to inspect vehicles for hazardous conditions before entering the storage area and, once loaded, before leaving the storage facility.
- DD Form 836. Prepared by storage facility for each driver of a vehicle that leaves the facility loaded with munitions. Drivers must keep the form in their possession at all times while transporting munitions.
- DD Form 1348-1A. Accountable document prepared by the shipper for each NSN/TCN combination. Includes ammunition management data required to process the transaction in SAAS. Also serves as MRO, confirmation or denial, and advance notice of shipment.
- DA Form 3151-R. Used to record storage locations of all items in the shipment. Tracks the movement of munitions within the storage facility.
- Placards and labels. Ensure that appropriate placards and labels are properly affixed to vehicles before loading.

PROCEDURES

3-50. The flowchart in Figure 3-4 below may assist in planning and conducting shipping operations and in writing SOPs. This chart can be modified to meet special requirements and conditions.

○ ASA
● MMC
□ Transportation Office
■ Convoy CMDR/Driver
▲ ASA Office
⊗ Checker
⊕ Inspector

No	Activity	Document	○	●	□	■	▲	⊗	⊕
1	Decide to Ship			●					
2	Initiate Materiel Release Order (MRO)	DD 1348-1A		●					
3	Receive MRO	DD 1348-1A					▲		
4	Verify Quantity on Hand, Condition						▲		
5	Select Lots, Storage Locations, and Quantity by Lot Suspension Status						▲		
6	Request Transportation with TCMD	DD 1384					▲		
7	Plan Movement, Nominate Carrier	DD 1384			□				
8	Prepare Stores Slips and MILSTRIP Documents	DD 1348-1A DA 3151-R					▲		
9	Review Lots on Suspension File	DA 3151-R							⊕
10	Review ASA Surveillance Record for Inspection Results	DA 3022-R							⊕
11	Perform Preissue Inspection, if Required								⊕
12	Verify Condition of Lots Selected	DA 3151-R							⊕
13	Return Stores Slip to ASA Office	DA 3151-R							⊕
14	Direct Any Required Preservation and Packaging						▲		
15	Alert Loading Crew, Checkers, Inspectors, MHE Operators						▲		
16	Direct Convoy to ASA	DA 1384			□				
17	Arrive at ASA--Park in Vehicle Holding Area	DD 1384				■			
18	Present TCMD to ASA Office	DD 1384				■			
19	Inspect Empty Vehicles	DD 626							⊕
20	Complete Preparation of Stores Slips	DA 3151-R					▲		

PLANNING PLANNING

Figure 3-4. Shipping Procedures

21	Distribute Stores Slips	DA 3151-R
	a. Original and Copy to Checker	DA 3151-R
	b. Copy With Suspense Shipping Documents	DA 3151-R
22	Escort Vehicles to Storage Locations	DA 3151-R
23	Load, Block, Brace, and Inventory Vehicles	DA 3151-R
24	Sign Stores Slip Jointly	DA 3151-R
25	Fill Out Magazine Data Card	DA 3020-R
26	Drive Loaded Vehicles to Assembly Area	DA 3151-R
27	Inspect Loaded Vehicles	DD 626 DD 836
28	Return Stores Slips to ASA Office	DA 3151-R
29	Verify Stores Slip Against Suspense Copy	DA 3151-R
30	Complete Shipping Document for Each Vehicle	DD 1348-1A
31	Total All Stores Slips--by Quantity and DODIC	DA 3151-R
32	Prepare and Sign Final TCMD	DD 1384
33	Release Convoy - Jointly	
34	Convoy Departs	
35	Post Records	SAAS
36	Provide Notice of Departure to Receiver	DD 1348-1A
37	Provide Materiel Release Confirmation to the MMC	SAAS
38	Record and File Documentation	ALL

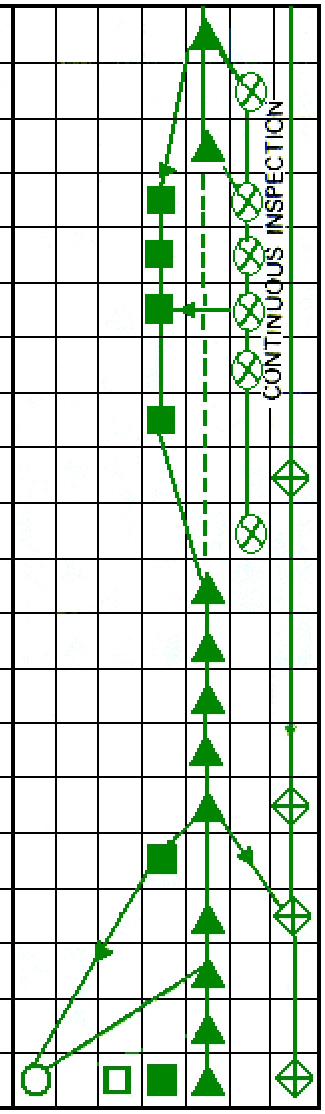


Figure 3-4. Shipping Procedures (Continued)

SUMMARY

3-51. Ammunition supply operations such as receipt, turn-in, issue, shipment, and retrograde are likely to be requested to support both combat operations and SASO. The theater or CMMC is a key organizational element in the shipment and retrograde process in terms of authorizing movement of munitions and packaging material. The MCA and its MCTs play a critical role in the transportation process.

Chapter 4

Division Ammunition Office and Ammunition Transfer Point

This chapter discusses the responsibilities, functions, and operations of the DAO and ATP sections within the division. It also covers the activities within division and corps structures that have staff and management responsibilities for munitions operations and planning during peacetime and contingency operations.

DIVISION AMMUNITION OFFICE

4-1. The Class V supply section of the DMMC is commonly referred to as the DAO. This section manages munitions for the division, provides staff supervision to division/brigade ATPs, and provides technical assistance and advice on munitions management to divisional units. Also, this section maintains records of munitions allocations, receipts, and expenditures for divisional units.

4-2. The DAO has administrative, operations, inspection, and ATP elements. Routine munitions duties and responsibilities may differ from one division to the next.

OFFICE ELEMENT

4-3. Within the Class V section, the DAO is the principal munitions staff officer for the division. The DAO assists the DISCOM commander in all matters pertaining to division munitions support and represents the DISCOM commander on matters concerning munitions requirements and availability. The DAO also maintains direct liaison with the division G3/G4 within limits defined by the DISCOM commander or DMMC chief. Other DAO responsibilities are as follows:

- Coordinates and controls use of Class V supplies.
- Monitors RSRs from tactical commanders for the G3.
- Monitors CSRs for the G4.
- Maintains munitions allocations for the division and approves munitions requests for users.
- Provides staff supervision for ATP operations.
- Maintains liaison with supporting CSAs and ASPs and the COSCOM MMC and MCC.

4-4. The senior munitions NCO is the principal enlisted assistant to the DAO and supervises all enlisted personnel assigned to the Class V section. Other responsibilities of the senior munitions NCO are as follows:

- Conducts on-the-job training to ensure proficiency and cross-training of enlisted personnel.
- Supervises preparation of all correspondence, plans, and reports and edits these documents prior to dispatch.

- Supervises maintenance of forms, files, and records.
- Serves as custodian for all classified documents.
- Ensures proper maintenance of all Class V section authorized equipment and vehicles.

OPERATIONS ELEMENT

4-5. The operations element provides technical advice and assistance on munitions supply, transportation, handling, and storage. The section supervisor is an ammunition warrant officer who provides the DAO with the current division munitions supply status. Ammunition supply sergeants perform stock visibility and clerical duties. Other responsibilities are as follows:

- Maintains stock visibility and supporting documentation and ensures availability of current information.
- Assists units in preparing munitions forecasts.
- Assists units on the storage, maintenance, and handling of ABLs.
- Reviews and updates basic load authorizations.
- Processes DA Forms 581, verifies unit forecasts, and monitors using unit submissions of DA Form 1687.

INSPECTION ELEMENT

4-6. Munitions inspection NCOs make up the DAO inspection element. This element advises on the safety, serviceability, maintenance, and security of all munitions assets in the division. It also evaluates division use of munitions storage and safety procedures in garrison and in the field and recommends improvements to these procedures. Other responsibilities of the inspection element are as follows:

- Inspects unit ABL and ammunition holding areas and ensures that units follow regulations and safety procedures.
- Observes and assists in investigations on munitions malfunctions.
- Coordinates with EOD teams.
- Maintains records and reports of munitions inspections.
- Monitors munitions suspension notices.
- Maintains specifications on packaging and storing of munitions.
- Uses applicable munitions load drawings to monitor and ensure proper and safe loading relative to munitions movement.

ATP ELEMENT

4-7. NCOs assigned to the ATP element of the DAO provide staff supervision of the forward ATPs. The DAO may also have representatives at the supporting CSAs and ASPs if enough personnel are assigned. Responsibilities of the ATP element include the following:

- Provide technical assistance, coordination, and advice to ensure munitions transfer operations at the ATP are conducted properly and efficiently.
- Monitor munitions flow into and out of the ATP.

- Authenticate DA Form 581 and ensure each request is within the CSR.
- Ensure only authorized personnel receive munitions based on the unit DA Form 1687.
- Keep the DAO informed through daily reports and ensure ATP operations comply with division SOPs.
- Assist the ATP NCOIC with selection of adequate ATP sites.
- Verify contents of corps resupply vehicles.
- Establish primary and backup communications with the DAO, the supporting ASA, and other agencies (i.e., FSB support operations offices and the brigade S4).
- Coordinate with the brigade S4 and FSB support operations office to schedule using unit resupply.
- Coordinate with operations element for backhaul of corps transportation assets.

AMMUNITION TRANSFER POINT

4-8. The ATP section of the FSB/CSB supply company operates the forward ATPs. The supporting DS ordnance company or modular platoon ATP section operates the rear ATP. Since the munitions support mission is such a critical one, the ATP section performs *only* munitions transfer operations. It is neither equipped nor staffed to perform other supply-related functions. The ATP section is primarily responsible for conducting munitions operations and maintaining stock status records of munitions.

4-9. Munitions operations include the transloading of munitions from corps trailers to user resupply vehicles under all environmental and threat conditions, receiving unit turn-ins, performing emergency destruction of munitions, and conducting relocations. This section is also responsible for the following:

- Controlling the flow of vehicles within the ATP to avoid congestion and to ease munitions handling operations.
- Consolidating trailers with less-than-trailer loads to economize resupply.
- Releasing transportation assets for backhaul.
- Defending the ATP from enemy threats.

4-10. To maintain visibility of munitions, the ATP section keeps type and quantity records of the balances of the munitions within the ATP. Paperwork and reports relative to munitions received from corps or users is passed along to the DAO representative as well as reports on damaged munitions.

ORGANIZATION

4-11. The ATP section is comprised of the section chief (an NCO) and section members. The section chief supervises operations under the staff supervision of the DAO. The number of personnel assigned to the ATP depends on the unit TOE authorization.

ATP Section Chief

4-12. Section chief/NCOIC responsibilities include planning and organizing ATP operations, supervising ATP section members, and developing the operations SOP. Other responsibilities of the section chief are as follows:

- Ensures all operations are conducted safely with consideration for operational hazards (i.e., fire protection).
- Disperses vehicles and conducts vehicle inspections.
- Signs and processes shipping documents, including DD Form 1348-1A.
- Ensures safe munitions handling.
- Manages ATP cover, concealment, and security.
- Maintains stock status records of munitions at the ATP.
- Ensures proper and continuous operator maintenance is performed on all section equipment, such as MHE, trucks, and radios.
- Establishes work schedules.

Because the ATP section operates independently in a support area, the NCOIC must keep the DAO representative informed of problems or added support requirements, such as personnel, MHE, security, or transportation assets.

Section Members

4-13. Section members have both munitions-specific duties and field operations responsibilities. Their responsibilities are as follows:

- Ensure safe handling of munitions within the ATP.
- Operate rough terrain forklifts used to transfer munitions from corps to user resupply vehicles.
- Perform preventive maintenance on assigned equipment.
- Reposition trailers to enhance operations.
- Maintain cover and concealment of the operations area.
- Assist with ATP security.

MUNITIONS-RELATED FUNCTIONS

4-14. Within the division, there are other organizations with functions critical to the division's ammunition support. Discussed below are the munitions-related functions of the maneuver battalion and brigade operations and training staffs and logistical staffs, the DISCOM, support battalions, and the general staff.

MANEUVER BATTALIONS/BRIGADES (S3)

4-15. Based on anticipated tactical operations, the S3 of each maneuver battalion determines munitions requirements and submits them to the brigade S3. The brigade S3 determines the consolidated munitions requirements for the brigade from the battalions' input and from knowledge of planned tactical operations. (The exception is artillery units whose requirements are determined through the DIVARTY.) The brigade's consolidated requirements are added to the requirements of divisions and nondivisional elements that are supporting the brigade. The total requirement is submitted to the division G3. The other important task of the maneuver brigade S3 is to select the location of the BSA.

MANEUVER BATTALIONS/BRIGADES (S4)

4-16. The S4 of each maneuver battalion requisitions munitions based on consolidated company requirements needed to support brigade operations. Munitions requests are submitted to the brigade S4 along with on-hand quantities, critical shortages, and forecasted changes in requirements. The brigade S4 consolidates the requests, coordinates with the FSB support operations officer to establish unit issue schedules, and provides the DAO with a unit issue priority list and consolidated unit requirements. Finally, the brigade S4 provides the battalion S4s with their allocations of the brigade CSR and advises the DAO to ensure that units do not exceed authorizations.

DIVISION SUPPORT COMMAND

4-17. The DISCOM provides logistical support to the division through organic support battalions and supports the maneuver brigades through the FSB. The MSB provides support to the division rear elements. More detailed information on DISCOM functions can be found in FMs 63-2 and 63-2-1.

4-18. Key staffs in the DISCOM are the S2/3 and the DMMC. With input from the DAO, the S2/3 prepares OPORDs and annexes for CSS and coordinates DISCOM assets needed to support the ATPs (i.e., MHE, personnel, DISCOM and corps transportation). The S2/3 also coordinates with the DAO on chemical munitions operations, distribution, and accountability control. When the division operates a series of base camps, consideration will be given to augmenting the DISCOM staff with a cell of QASAS/qualified military inspectors to provide explosives safety and ammunition technical services to the division.

4-19. The S2/3 exercises division-level movement control through the MCO, an agent of the DISCOM commander who controls the use of motor transport assets for division CSS operations. Users forward their transportation requirements to the MCO. The MCO tasks the TMT company of the MSB and/or equivalent organizations, coordinates with the DMMC to ensure that supply movement priorities are met, and passes transportation requirements that exceed division capability to the DTO for further coordination and action.

4-20. Through the support operations branch, the S2/3 ensures that division support operations are conducted efficiently. This branch directs CSS elements of the division, ensures that SOPs governing CSS operations are prepared and followed, and prepares appropriate CSS directives and OPORDs for DISCOM internal operating elements (i.e., the FSB, MSB, and DMMC).

4-21. The DMMC manages supplies for the DISCOM. It determines division requirements and maintains supply records. It also directs the receipt, temporary storage, issue, and distribution of supplies and equipment, and provides command and control over the Class V supply section.

SUPPORT BATTALIONS

4-22. The ATPs are organic assets of the supply company in the FSB. Each FSB is in direct support of a maneuver brigade. The TMT company of the MSB distributes supplies to the FSB. Also, the TMT company can provide emergency munitions line-haul to augment corps transportation.

DIVISION GENERAL STAFF (G3 AND G4)

4-23. The G3 establishes the division RSR (based on consolidated RSR information from the brigades and anticipated combat requirements) after consulting with the DAO, DISCOM commander, G4, and other staff members. The division RSR is then submitted to the corps or equivalent organization for further planning and action.

4-24. It is important that the G3 keep the DAO informed of tactical situations that may impact on munitions operations. Such information may include the current and projected divisional tactical situation, weather, terrain, potential problem areas, MOPP levels, and munitions requirements other than those provided by the brigades.

4-25. The G3 manages emergency munitions resupply and determines priorities, needs, and (with the DAO) methods for performing emergency resupply operations. The G3 also coordinates with the DISCOM commander and G4 to determine the location of the DSA.

4-26. Based on the CSR received from higher headquarters (i.e., corps or theater), the G3 sub-allocates the division CSR. The CSR is published either in OPORDs, fire support annexes, or similar documents for the combat units.

4-27. The G4 also provides planning for division movement support through staff supervision of the DTO. The DTO serves as the communications link for transportation between the division and the corps and requests corps transportation support from the MCA. Further, the DTO provides DISCOM MCO guidance and assistance on division movement priorities, unit movements, movement requests, and MSR use and validates airlift requests for CSS operations.

ECHELONS ABOVE DIVISION

4-28. As directed by the COSCOM, the CSA and ASP support the ATP. These storage areas are corps assets assigned to COSCOM ordnance battalions/corps support battalions, companies, or platoons. They support the ATPs by preparing and shipping munitions in MCLs or single DODIC loads. When workload allows, and the DAO has provided the required information, the CSAs and ASPs may prepare preloaded ATP trailers and hold them until needed for resupply. These prepared trailers can be used either for emergency resupply or as part of the normal push to the ATP. CSAs and ASPs also issue munitions to units operating in their areas.

4-29. Higher level MMCs provide commodity management and inventory visibility control of munitions. The CMMC manages munitions at the corps level only and interfaces with the operational level MMC. The operational level MMC manages assets for the entire theater and is the primary interface between the theater and the NICP, DLA, and USAMC.

DAO AND ATP OPERATIONS

4-30. Munitions support to the division involves two basic functions. The first is planning and the second is execution. Both are accomplished by the DAO's Class V supply section and the supply company's ATP section.

4-31. The Class V supply section's planning function focuses on how to logistically support the commander's tactical plan so that the right munitions are available at the right place and time. The section's execution function is to monitor the distribution and flow of munitions during battle.

4-32. The ATP planning function is to coordinate resupply of combat units with the arrival of incoming munitions shipments. Its primary execution function is the transloading of munitions to combat units.

4-33. How well these sections perform their functions directly affects the quality of munitions support to the division. All operations involve close coordination between the two sections.

DAO OPERATIONS

4-34. The Class V supply section supervises the ATP staff and manages munitions. The DAO determines the amount of munitions needed to support the division based on the tactical plan and established CSR. Also, the DAO decides how to distribute munitions available in the ATPs to best support users. The DAO coordinates with the supporting CMMC and CSAs and ASPs for resupply and continually monitors tactical requirements to modify resupply requirements. Planning will address the types and quantities of munitions required and identify the ATPs to which the munitions will be delivered. Some of the more important responsibilities of the DAO are discussed below.

SOPs and OPLANs

4-35. The DAO publishes SOPs and develops portions of OPLANs to ensure plans and procedures that adequately support the tactical forces are established within the division. Before implementing SOPs and OPLANs, they must be carefully coordinated with the support battalion.

4-36. The DAO determines and publishes the support plan for each ATP so that all supported units know the identity and location of their supporting ATPs. The DAO provides the G3 with ATP information to be covered in OPLANs and OPORDs, including DAO, storage area, ATP, and CSA locations.

Division Resupply Requirements

4-37. Anticipated tactical operations drive division resupply requirements. The DAO estimates these requirements using information from the automated OPLOG Planner, input from the brigades, and knowledge of the force to be supported. Either the brigade S3 provides weapon status information, or it is obtained from the weapon systems status report submitted through logistics channels (S4/G4). This report gives the current status of on-hand weapon systems in the maneuver battalion.

4-38. SIDPERS reports provide current personnel data when troop strength is the basis for munitions allocations (as is the case with hand grenades, flares, simulators, and so forth). The DAO uses historical data for the particular force/scenario or planning rates in the OPLOG Planner when anticipating combat losses.

4-39. Added planning and coordination are required to support nondivisional and corps slice elements (i.e., an artillery battalion supporting a maneuver brigade). The overall division munitions planning process must include organizations, or portions of organizations, that normally support the division. The DAO will maintain close coordination with the operational and logistical staff elements of these nondivisional elements. Such coordination enables the munitions planner to anticipate requirements.

4-40. In coordination with the G4 and the CMMC and based on proposed MCL configurations submitted by the maneuver brigade S4, the DAO computes the numbers and types of MCLs required to support the division. MCLs are preplanned packages of munitions that consist of items needed to support a particular type unit or weapon system. The MCL concept differs from previous resupply concepts. With this concept, the ATP supplies a fully functional package loaded on flatrack(s), instead of multiple single DODIC platforms located throughout the ATP.

4-41. The CMMC consolidates data from all assigned divisions and nondivisional elements as appropriate (such as corps artillery) and completes composition of the MCLs. The DAO translates the user munitions allocation, which is based on CSRs, into MCL packages and submits these requirements to the CMMC. With knowledge of how much of what MCL is required at each ATP, the CMMC can continue to push munitions if communications systems fail.

Division Munitions Status

4-42. The DAO monitors the division ATPs to determine the availability of all types of munitions. Also, the DAO checks on the ETA of incoming shipments and notifies DAO representatives and support operations sections of the support battalions. The DAO locates representatives at the ATPs or on MSRs to coordinate and control munitions flow and to direct redistribution of munitions in the ATPs to support combat units more effectively. In peacetime, the DAO monitors all ABL and operational or contingency stocks to ensure availability and serviceability.

EMERGENCY REQUESTS

4-43. Under the push system, munitions are specifically requested only in emergencies. Preplanned munitions continue to flow until the MCLs are changed either in type or quantity to be delivered. A munitions shipment is said to be “throughput” when it bypasses one or more nodes; it is used to improve efficiency in the distribution process when emergency requirements dictate.

4-44. Emergency throughput involves corps transportation assets historically not employed near the front lines. For this reason, the corps G3 makes the decision to conduct the operation, based on the requirement and the recommendation of the DAO.

4-45. Several methods may be used for throughput of emergency requirements. Whichever the method, it is essential that close coordination and communications be maintained among the users, the DAO, the G4, and transportation units. The division SOP is the appropriate medium for specifying requirements and procedures to be followed.

4-46. Combat units pass emergency requirements for munitions through G3/S3 channels to the DAO as quickly as possible. The DAO selects the fastest method of responding to the requirement, based on its priority as determined by the G3. Possible solutions include diverting inbound shipments from ATPs that are supporting units with less need, using aerial resupply, using throughput procedures previously described, or using a combination of these. The DAO implements emergency resupply solutions and monitors the action to ensure effective and efficient resupply.

Chemical Munitions

4-47. Chemical munitions do not remain in an ATP for long periods of time. Based on a materiel release order from the CMMC, they are pushed forward to the ATP and then issued directly to the using unit. Chemical munitions require chain of custody documentation using DD Form 1911. The ATP may receive chemical munitions from either the CSA or ASP. The ATP assumes custody and coordinates security until the munitions are issued. Also, the ATP may serve as a transfer point for retrograded chemical munitions. The DAO and ATP representative closely monitor receipt of chemical munitions and ensure that units are notified to expedite issue and limit ATP handling time. Specific controls for chemical munitions are covered in AR 50-6.

Records and Reports

4-48. Although the amount of detail may be reduced, combat operations or SASO do not eliminate the need for keeping records and preparing reports. The division must still be able to track its munitions status to be an effective combat force. The DAO must keep records for each ATP of the on-hand status, munitions issues, munitions requirements (to help establish usage data), requirements documents, and authorized expenditure rates (CSR/RSR).

Authorized Rates

4-49. No prescribed format exists for transmitting RSRs or CSRs, but it is imperative that they are transmitted through both operational and logistical channels (i.e., OPLANs, OPORDs). The DAO receives CSRs from the G4. The DAO representative at each ATP must ensure that units do not exceed their CSRs by maintaining authorization information for each supported unit, including divisional and supporting corps-slice elements. When the DAO representative authenticates a user's munitions requirement document, the unit authorization is reviewed. Any previous issues are subtracted to determine the quantity of munitions the unit is authorized. The S4 of the supported brigade will provide CSR data for each unit the ATP supports.

4-50. To monitor CSRs, the DAO can use either SAAS-DAO/SAAS-ATP or a manual system consisting of stock record decks. If a manual system is used, it will allow the user to maintain visibility of all assets, process documents quickly, and prepare status reports easily.

Document Flow

4-51. Even with emerging automated procedures, the Class V supply section and ATP should keep some manual forms and process some documents to maintain good munitions control. The following section discusses some of the important documents that the DAO and ATP NCOIC are likely to encounter. Detailed documentation processing is discussed elsewhere in this manual.

4-52. **Shipping documentation.** Corps storage areas ship munitions to the ATP using DD Form 1348-1A, DD Form 1384, and if necessary, a DD Form 1911 for chemical munitions. The transportation system uses DD Form 1384 to control the shipment throughout the shipping process. This form includes information basic to shipping and transportation activities (i.e., type of shipment, mode of shipment, special handling information, required delivery date, lot number, number of items, weight and volume of items and total shipment).

4-53. The ATP NCO verifies the actual shipment against these documents to ensure that the correct items and quantities have been shipped and makes corrections, if needed. The documents are then signed and returned to the Class V supply section for processing. Stock records at the ATP are posted using either SAAS-ATP or manual records.

4-54. The REPSHIP is another document used for shipping. The REPSHIP alerts the receiver (i.e., DAO or ATP) to a pending shipment and provides the ETA, a listing of items and quantities shipped, and special instructions for transportation agencies and receiver. The ATP either uses the REPSHIP to plan for receipt of the shipment or arranges to meet the convoy in case the ATP has to relocate while the convoy is en route. Although the DD Form 1348-1A may be used as a REPSHIP, no standard form or format is prescribed. The theater may direct the use of the most suitable format. Any available media may be used to transmit REPSHIP data.

4-55. **Issue and transload documentation.** The main document needed to perform munitions issue or transload operations is DA Form 581. The S4 of the using unit requests issue of munitions on the DA Form 581 within the authorized quantities (CSR) provided by the brigade S4. Before releasing the unit to transload, the DAO representative at the ATP verifies that the request is within the unit CSR and that the ATP has the required amount. If either the CSR or the ATP quantity will be exceeded, the DA Form 581 must be amended. The DAO representative also checks the DA Form 1687 to ensure that the unit representative is authorized to draw munitions.

4-56. Once munitions are transloaded, the ATP representative verifies the load with the unit representative to ensure the unit gets the right type and amount of munitions. This procedure also helps to maintain munitions visibility. When the unit departs, the DAO representative posts the issue to his control records and reports the transaction to the DAO through the DTR.

4-57. **Daily transaction reports.** The DAO updates and verifies records using DTRs submitted by the ATP representatives. The DTRs will be limited to pertinent munitions information and problems/anticipated operations that would affect the flow of munitions. A short SITREP should accompany the DTR. The report period depends on the situation, command procedures, and common sense. However, twice daily reports should be considered reasonable.

4-58. The DAO also uses the DTRs to compare balances with estimated requirements and submits a consolidated balance report to the CMMC IAW the SOP. Any serious or important information may be included with the balance report.

4-59. **Munitions status report.** The division will develop a simple and standardized AMSTAT to report its munitions status to higher headquarters. The DAO provides consolidated information from the ATPs via the DTRs and adds any pertinent information. Various formats may be used based on the report's intended purpose. The AMSTAT must be classified at a level high enough to keep from revealing important logistical and/or tactical information. It may be submitted electronically or by direct computer link. The corps determines the AMSTAT addressees, but at minimum it is sent to the corps and division G3s and G4s and division units with action. Information copies will be provided the CMMC.

Surveillance Operations

4-60. Surveillance operations ensure that munitions are safe for issue and use. These operations include the observation, inspection, and classification of munitions and components during storage and movement. Extensive inspections are not expected during combat but should be expected during SASO. They may be required, however, to conserve valuable or critical munitions assets and to ensure that serviceable munitions are issued to using units. The ATP-level inspector is mainly concerned with munitions suspension or restriction control, weapon malfunctions, and ABL inspections. Supporting DOD QASAS/qualified military inspectors will perform serviceability inspections of all ammunition transferred from one unit to another when the tactical situation permits. Such transfers will be the exception to normal operations but are warranted in such situations as unit rotations during SASO.

Munitions Suspensions

4-61. The ATP will issue only serviceable munitions to combat users. Some munitions may be determined to be unsuitable for combat use due to deterioration, age, storage conditions, or manufacturing defects. Such munitions may be classified as suspended or restricted and are unsafe to use or move for a variety of reasons. Use of suspended munitions can pose danger to the weapon crew. Restricted munitions are items safe to move, store, or use under the proper conditions. (For example, particular lots of faulty artillery shells that have been specially tested and approved as safe for use only in overhead fire operations.) TB 9-1300-385 contains the current worldwide list of suspended and restricted munitions.

4-62. When munitions are discovered to be dangerous, suspension or restriction notices are sent to all affected organizations as quickly as possible. The Class V supply section inspector monitors these notices.

4-63. The DAO requests disposition instructions from the CMMC for unsuitable munitions within the ATPs and coordinates with the CMMC to determine if the ATPs will be resupplied. The DAO directs the ATP NCOIC to mark and segregate (to the extent possible) the suspended/restricted munitions. The DAO then notifies all units that received suspension or restriction notices and coordinates through the battalion S3 to arrange for turn-in and reissue.

4-64. If the CMMC directs that the munitions be destroyed, they can be destroyed by ordnance personnel. The disposal site must meet disposal guidelines IAW DA Pam 385-64 and the MMR. If EOD personnel are required, the division G3 will coordinate with the supporting EOD unit for assistance.

Weapon/Munitions Malfunctions

4-65. Weapons and munitions do not always function as intended in combat. Occasionally malfunctions do occur. Combat units must notify the DAO of the malfunction as soon as possible. The DAO notifies the CMMC and the ordnance battalion/corps support battalion for inspection support. Besides DAO inspectors, investigation of munitions malfunctions may require the assistance of QASAS/qualified military inspectors for inspection and resolution. Based on this inspection, munitions may be suspended locally pending a more thorough investigation.

ABL Inspections

4-66. ABL must be periodically inspected to ensure proper and safe storage. During combat, some munitions storage standards may be relaxed. Both civilian and military munitions inspectors will inform commanders of the risks involved. Inspection requirements are discussed in SB 742-1. Command policies will contain provisions for the cyclic scheduling, supporting, and accomplishment of inspections of ammunition in the possession of units. This is an explosives safety force protection measure.

ATP OPERATIONS

4-67. The ATP section of the FSB supply company operates the brigade ATP in close coordination with the DAO, FSB, brigade, division staff, and supporting/supported organizations. Activities and responsibilities of the ATP section are described below.

Site Location and Selection

4-68. For the most part, the ATP section plans for and establishes the ATP, which must be properly sited in the support area (brigade/division) to support combat operations. The maneuver brigade S3 sites the BSA, and the division G3 determines the DSA location.

4-69. The DAO, ATP NCOIC, and brigade and division staffs will provide input to the ATP site selection. The DAO provides munitions-related technical information and suggestions on how best to lay out the ATP for support operations. Following site selection, the best layout for the ATP must be planned and executed.

4-70. As the division munitions expert, the DAO provides input on the proper positioning of ATPs on the battlefield. ATP section personnel do most of the planning and physical setup of the ATP. However, the DAO ensures that it is positioned to most effectively support combat users, given the munitions requirements of the supported force and the tactical factors of METT-TC. The DAO coordinates placement of the rear ATP with the division G3 and placement of forward ATPs with the supported brigade S3 and the support battalion. An ATP is normally part of the BSA. Depending on the tactical situation and METT-TC, it may also be located at a railhead, shipyard, port of debarkation, or at an ASP or CSA or adjacent to a road network.

Site Layout

4-71. No specific standard configuration exists for ATP layout. Layout will be based on the tactical situation and what is deemed to be the most functional way to provide support to using units. See DA Pam 385-64 for additional guidance. The MCL concept increases the capability of the ATP to support a specific type of unit with one-stop transloading rather than multiple stops to fill munitions requirements. However, it still may be necessary to maintain trailers with single DODIC loads to replenish other type units. The DAO and ATP section must analyze the support situation and determine how best to support users.

4-72. Some layout considerations are common to any configuration. One entrance/exit point, with consideration for an emergency exit, allows control of unit and corps vehicles and MHE. A good one-way roadnet should have room to allow unit vehicles and MHE to operate safely. A separate holding area should be available to hold incoming trailers temporarily that cannot be placed immediately.

4-73. The signature of the ATP should be reduced using terrain features such as vegetation, trees, slopes, and valleys for concealment. Special care must be taken not to disrupt the natural look of the area.

Receipt Of Munitions

4-74. The key function of the ATP is to receive munitions from CSAs/ASPs, on corps transportation assets, and transload them to user resupply vehicles. Current analysis estimates the receipt of shipments at every three to four hours, which realistically translates to continuous operations. Receipt is, therefore, the most important operation.

4-75. The DAO representative and the ATP section must be prepared to properly receive and place trailers, transload to users, and record and report the receipt. Munitions may also be received from other ATPs when the DAO directs redistribution in support of the division or as turn-ins of unused or unusable munitions. Within CSR constraints, the DAO must ensure the availability of munitions stocks at ATPs to support user needs. During SASO, the ATP may be required to store limited amounts of munitions stocks.

4-76. **Receipt Planning.** The shipper will notify the ATP in advance of a scheduled shipment either by hard copy or electronic REPSHIP, or DD Form 1384. In combat, SAAS-DAO communication is the probable means of advance notification. The DAO also informs the receiving ATP representative of the ETA and types and quantities of munitions expected.

4-77. The planning process at an ATP is continuous. When an advance shipment notification is received, the ATP section must know where to place the trailers, consistent with different hazards and storage standards, to ensure safe operations.

4-78. **Receipt Documentation.** The ATP representative will verify shipment contents against the shipping documents (i.e., DD Form 1384 and DD Form 1911 for chemical munitions). The ATP section assists by helping with the count. The ATP representative must record any discrepancies and damaged munitions on the shipping documents and, time permitting, record the quantity of munitions by lot number for DAO records.

Vehicle Inspection

4-79. Munitions are especially sensitive to fire. Before entering the ATP, convoy tractors and trailers and using unit vehicles must be inspected for safety defects that could start or contribute to a vehicle or grass fire. Inspection criteria are stringent during peacetime operations. In combat or SASO and based on mission requirements, the criteria may be relaxed to speed munitions flow. However, this must be a documented command decision. The inspection criteria of DD Form 626 will be used as much as possible.

Trailer Placement

4-80. When placing trailers, the NCOIC has two considerations. The first is how to best support the units. If possible, place unit loads or MCLs in the same general area. If the munitions are issued by DODICs and not by MCLs, trailers of the same DODICs should be located together. The second consideration is the characteristics of the munitions. Munitions must be stored correctly to reduce hazards to the ATP. Consult DA Pam 385-64 for specific guidance. Chemical munitions will receive special attention because of added hazards and security needs.

Escort And Release

4-81. ATP section personnel should escort tractors to ensure that trailers are properly positioned and recorded on a planograph or locally prepared site log. After trailers are placed, the drivers pick up any trailers to be backhauled to the rear. Once the return convoy is established, the DAO representative provides a copy of all documents to the convoy commander and releases the convoy for the return to the CSA.

Munitions Returns

4-82. Using units return very few munitions since most will have been expended. However, munitions that are returned must be handled carefully. Users can return munitions that are suspended or restricted or because they are excess to basic load requirements. Combat units may also turn in CEA.

4-83. The DAO representative notifies the DAO of returns using the daily AMSTAT. If the munitions are unserviceable, the DAO requests disposition instructions from the CMMC. If the munitions are returned as serviceable excess, the DAO redistributes them to users.

4-84. Returned munitions can create problems. The most significant of these are the following:

- Arrival of unit returns with little or no warning. The ATP NCOIC should anticipate user returns and set aside areas of the ATP for returned munitions. Accepting returns should be regarded as part of a normal day's operations.
- The potentially hazardous condition of returned munitions. This problem is more dangerous since the munitions may pose serious safety hazards, depending on their characteristics and condition.

To help reduce storage hazards, ATP personnel will mark returned munitions and store them separately from serviceable munitions. As soon as mission permits, an ammunition inspector will assign an ammunition condition code and determine if any suspensions or restrictions are applicable. This practice prevents inadvertent issue to using units and the possibility of a safety hazard.

Unit Issues

4-85. Thorough preparation by all key players is essential to an efficient issue operation. The battalion S4 prepares the request for issue on a DA Form 581 and coordinates resupply schedules with the brigade S4, the support operations officers, and the DAO. The support operations office coordinates with the DISCOM S3 to schedule supported units. The FSB SPO, in conjunction with the DAO representative, will work with supported units to ensure that forecasted munitions are properly receipted.

4-86. When the S4 notifies the DAO of the requirement, the DAO decides how best to support it and determines if the required munitions are in the supporting ATP. The DAO also ensures that the requirement is within the CSR or that an increase has been granted. If the munitions are at the ATP, the using unit can go to the ATP and transload; if not, the DAO must determine how to support the unit. If required, the DAO arranges emergency resupply by coordinating with the unit, the division G3, and the CMMC.

4-87. Before entering the ATP, using unit vehicles must be inspected for safety defects that could be hazardous to the ATP or its personnel. Vehicle inspection procedures are covered in other chapters of this manual.

4-88. While the ATP section inspects the unit's resupply vehicles, the DAO representative authenticates the DA Form 581, verifies that the unit requirement is within CSR limits, and ensures that the ATP has the required quantities. If the requirement exceeds the CSR or the munitions are not in the ATP, the DAO representative requests instructions from the DAO.

4-89. After transloading, the DAO representative verifies the issue and ensures that the correct types and quantities of munitions have been issued and loaded safely on unit vehicles. Once the unit is released, the DAO representative and ATP NCOIC update their munitions records. The updated records allow preparation of the AMSTAT and asset control within the ATP.

Operations Safety

4-90. ATP section personnel must operate the ATP safely and maintain its assigned equipment. The ATP NCOIC ensures that all operations are conducted as safely as possible. The most significant danger in an ATP is fire. MHE movement and transloading also present significant hazards. See Chapters 7 and 8 for operational and fire safety precautions and provisions applicable to munitions storage facilities and operations.

ATP Relocations

4-91. The purpose of the ATP is to provide dedicated munitions support to the user as far forward as possible. When the supported force maneuvers, the ATP moves accordingly. Routinely, the ATP should be prepared to move frequently, as METT-TC dictates. Detailed plans will be established to allow for quick, orderly movement under pressure. Evacuation priorities will be established beginning with the most important assets. Except for the emphasis on speed, the basic procedures for an emergency move are the same as for a routine move.

4-92. When planning for relocations, the following factors must be considered:

- First, the move must be thoroughly planned. Preparation and practice during peacetime (IAW a well developed SOP) increases the capability to move effectively and reduce confusion during wartime.
- Second, the ability to maintain communications is extremely important.
- Third, support to the brigade from the corps munitions structure and lines of communications between supported units and with the corps must be maintained. Disruption of munitions flow in support of the brigade should be minimized to the extent possible.

4-93. The ATP is moved in phases to maintain continuity of support to the combat users. A portion of the ATP may move to establish a new site, and the remainder may move later and establish full operations. The relocation can be divided into three phases: pre-movement, movement, and post-movement.

4-94. **Premovement.** Planning input and coordination by the DAO, G3, G4, and ATP section ensure that a coordinated, safe, and quick relocation is conducted. Relocation plans must be coordinated with all supported and supporting agencies. The DAO coordinates with the CMMC for the move. This includes arranging for corps transportation to move the munitions to the site and for the backhaul of empty trailers at the old site. Also, the DAO notifies the support operations office of the closure and arranges for users to draw as much as possible, which effectively reduces the amount of munitions to be moved with corps assets. The DAO representative assists with reconnaissance of the new BSA site and provides munitions and trailer status to the DAO.

4-95. The ATP section conducts the actual move with coordinated divisional or corps transportation assets. It must consolidate munitions on as few trailers as possible, break down the area, and prepare the equipment and vehicles for movement.

4-96. The support operations office notifies the supported brigade of the intended move and provides information about closure of operations at the old ATP and the initiation of operations at the new site. The support battalion provides the necessary division assets and coordinates for corps assets to conduct the relocation. The S2/3 requests prime movers to move munitions and MHE. Also, the S2/3 prepares the overall FSB and MSB movement plans, including convoy operations.

4-97. **Movement.** During the movement phase, the BSA or DSA establishes the advanced element at the new site. The ATP NCOIC provides this element with MHE and personnel to support the brigade until normal resupply operations can be established. The support battalion organizes the convoy for movement to the new site. The CSA/ASP begins to ship to the new ATP site as soon as possible.

4-98. **Post-movement.** The DAO representative and the ATP NCOIC set up the new ATP site and prepare to conduct normal ATP operations. In doing so, they ensure that the old site is closed and all equipment, stocks, and personnel have been relocated to the new site. The old ATP site must remain open long enough to provide continuity for all users and resuppliers.

SUMMARY

4-99. This chapter has provided a general overview of the organizational structure and operational requirements of the DAO and the ATP. Also, it has established the functional link between the division and corps ammunition structure. Effective DAO and ATP operations are critical to the combat power and sustainability of the division and its brigades. Trained and prepared Ordnance soldiers are key to effectiveness.

BRIGADE COMBAT TEAM AMMUNITION OFFICE AND AMMUNITION TRANSFER POINT

The Interim Brigade Combat Team is scheduled to be operational in fourth quarter, fiscal year (FY) 2000. Its design gives the Army a rapidly deployable, highly mobile, survivable, and lethal force intended to fill the void between traditional heavy and light forces. Planners have incorporated the principles of velocity management, reach-back support, and regionally available commercial support to the maximum extent possible to reduce the brigade's combat support and logistics footprint. Organic noncombat equipment has been drastically reduced with the expectation that the brigade will operate in an extremely austere environment until the theater matures. The existing ammunition support structure has been adapted to provide efficient and effective support. Elements tailored to support the BCT include the ATP and the BAO, a brigade-level element similar in structure and function to the DAO. These adaptations may be changed or modified before activation of the initial brigade.

AMMUNITION TRANSFER POINT. The ATP section will be assigned to the supply support platoon of the headquarters and distribution company, which in turn is assigned to the brigade support battalion. The headquarters and distribution company provides the majority of organic transportation and supply support to the BCT.

The ATP section's ability and requirement to reconfigure ammunition loads is limited. Ammunition arriving at the ATP will be in mission or customer configured loads that have been configured outside the theater (i.e., usually at a depot, an ISB, or remote ASA).

The BCT ATP will conduct limited storage operations. Unlike the traditional ATP activity, which is considered an event and not a storage facility, the ATP will support the BCT in SASO or small-scale contingency operations with little or no ammunition consumption.

BRIGADE AMMUNITION OFFICE. The BAO consists of an ammunition warrant officer and a senior NCO assigned to support operations of the base support battalion. The BAO's primary duties and responsibilities are comparable to those of the DAO discussed earlier. However, the BAO will coordinate mainly with the next lower echelon of staff offices (i.e., the brigade S3/4 instead of the division G3/4).

The BAO warrant officer may be the senior or most experienced ammunition logistician in theater, while the DAO staff will most likely have an MMC team and/or ASA comprised of Ordnance personnel supporting the division-level deployment.

The BAO will operate SAAS-ASP in lieu of SAAS-DAO. Also, the BAO may be required to establish direct communications with and report to the supporting MMC. This may occur in situations where no other levels of SAAS are deployed to the theater.

Chapter 5

Munitions Support in an NBC Environment

This chapter discusses munitions support in a theater of operations for combat or SASO, where NBC weapons have been used or are available for use. This information also applies to WMD situations. The information contained herein supports current Army doctrine and should be used with emerging NBC defense doctrine.

OVERVIEW

5-1. All combat operations or SASO have the potential to occur in an NBC environment. US policy neither condones nor authorizes first use of biological and chemical weapons. US policy concerning nuclear warfare is to deter and, if deterrence fails, to terminate the conflict at the lowest possible level of violence consistent with national and allied policy objectives. This policy does not preclude US first use of nuclear munitions.

5-2. Commanders and planners must assess an enemy's willingness to employ these weapons and the conditions that would prompt them to do so. For example, a virtually defeated enemy may resort to unrestricted warfare by any means to turn the tide of battle.

5-3. Use of WMD can result in extensive destruction and mass casualties. Only cohesive, disciplined, physically fit, and well-trained munitions units are able to function in an NBC environment. Long-term operations in this environment degrade even the best-trained soldiers. The wearing of NBC equipment for long periods decreases the ability of a munitions unit to provide support. Munitions leaders must train and equip all personnel to endure these conditions. By being prepared, munitions units can continue the support needed for combat forces to maintain the advantage over the enemy.

5-4. Command is more difficult in an NBC environment. Command, control, and support operations areas are likely targets. Control is difficult even within the smallest operation. The employment of WMD greatly alters the tempo of combat support, which in turn affects the combat mission. Munitions leaders must never assume they are immune to attack and need to consider ways of decreasing risk.

NUCLEAR WEAPONS

5-5. The immediate effects of a nuclear detonation are blast, thermal radiation, initial nuclear radiation, and EMP. These effects can cause significant personnel and materiel losses. Secondary effects include urban devastation, fires, and radiological contamination. EMP can affect unshielded electronic equipment and degrade C3I systems. Also, residual radiation can have long-term effects on personnel, equipment, facilities, terrain, and water sources. Munitions units and activities may be targeted for nuclear weapons attacks.

BIOLOGICAL WEAPONS

5-6. Although the US has renounced the use of biological weapons, many nations have not. Availability of biological weapons to potential enemies requires munitions leaders to prepare for operations in a biological environment. Defensive measures must be employed to reduce the effects of a biological attack. All munitions soldiers and civilians must receive adequate information, along with psychological and medical preparation.

CHEMICAL WEAPONS

5-7. Chemical weapons produce immediate and delayed effects that hamper operations by contaminating equipment, supplies, and critical terrain. Munitions leaders can reduce the effects of chemical use by applying the fundamentals of contamination avoidance, protection, and decontamination. Munitions leaders use chemical reconnaissance and decontamination as two planning imperatives for all missions. *Training is key.*

NBC DEFENSIVE FUNDAMENTALS

5-8. NBC defensive fundamentals include contamination avoidance, protection, and decontamination. Performing these fundamentals counters the effects created when WMD are used. Normal operations become more difficult, and overall efficiency is reduced. Munitions leaders must consider mission degradation and hazards when employing defensive fundamentals.

CONTAMINATION AVOIDANCE

5-9. Contamination avoidance is key to providing munitions logistical support in an NBC environment. It is also the key to survival. Contamination avoidance consists of a number of individual and unit preventive measures that can be both passive and active. Passive measures include the use of concealment, dispersion, deception, cover, and OPSEC. These measures reduce the probability of an enemy using WMD and limit damage if such weapons are used. Active measures include detection, identification, marking contaminated areas, warnings, and relocating or rerouting to uncontaminated areas.

5-10. To increase survivability and supportability, munitions units must act quickly to avoid contamination, improve mobility, and lessen initial and residual effects of WMD. The following must be used whenever possible:

- Alarm and detection equipment.
- Dispersion (consistent with operational requirements).
- Overhead shelters.
- Shielding materials.
- NBC-hardened materials.
- Protective covers.
- Chemical-agent-resistant coating paint.
- NBC reconnaissance assets.
- Intelligence assets and reports.
- NBC-hardened shelters and tents.

5-11. Munitions stocks should be stored at dispersed sites. This helps to reduce the effects of WMD and complicates the enemy's target acquisition efforts. Also, munitions must be kept separate from other supplies and as mobile as circumstances allow. Resupply operations should be accomplished at night. All these measures work to keep the munitions support system functional and capable of supporting tactical missions.

NBC Reconnaissance

5-12. Munitions units perform NBC reconnaissance within their AO. Specialized NBC reconnaissance units conduct reconnaissance outside the unit AO and the COMMZ. They provide contamination information to leaders, which assists in developing operational plans. NBC reconnaissance units report to NBC centers where information is analyzed and disseminated to units through periodic intelligence reports. Other units, other services, and allied units operating in the area provide added data. All this information combined gives leaders a more complete picture of the AO.

Detection and Identification

5-13. All units use organic detection and identification equipment to identify NBC items. With fielding of BIDS, munitions units will have an effective system for detecting and identifying biological agents. However, enemy forces may use biological and chemical items unknown to the US and beyond the capability of our identification equipment.

5-14. NBC reconnaissance and medical and intelligence personnel sample suspected CB items and forward the samples to supporting medical activities for identification. Once agents are identified, the information is transmitted to units through the NBC reporting center.

NBC Warning and Reporting System

5-15. The ASCC operates a network of NBC warning and reporting centers. These centers provide information about NBC hazards and are the focal point for NBC battlefield contamination information. The NBC centers collect, consolidate, evaluate, manage, and disseminate NBC data reported by units, and interface with adjacent friendly and allied organizations. Through operations channels, they provide the evaluated NBC information to units in their AO. The unit leader uses this information to plan and execute the mission.

Limiting Exposure

5-16. Detection and identification of WMD within the munitions unit AO limits exposure and adverse effects on munitions support operations. Units use organic detection and identification equipment to receive early notification of CB attacks. This early warning allows unit personnel to limit exposure by donning appropriate protective clothing. Also, BIDS helps limit the effects of large area attacks employing potentially catastrophic biological agents. Using data collected by BIDS, medical personnel can determine what preventive measures and treatment are required if exposure occurs.

PROTECTION

5-17. Protection is initially an individual responsibility. At minimum, personnel must have IPE; this allows them to operate freely in a contaminated environment, but not without some degradation. Collective NBC protection provides rest and relief from continuous wear of IPE and a contamination-free work area for critical missions. Type I functions (i.e., C3I and light maintenance) are best performed while using some form of collective protection. Type II functions (i.e., storage, receipt, issue, and load configuration) require IPE with periodic breaks for rest and relief. Movable collective protection can be provided to those areas on a site where its not feasible to permanently emplace collective protection. Moveable collective protection could be placed at storage, receipt, issue, and load and configuration areas. Temporary rest and relief shelters should be provided as break areas within the ASA or ATP.

5-18. Munitions leaders must provide proper training in protection skills. Before encountering an NBC hazard, munitions units use MOPP and other available protective means to balance unit effectiveness with personnel survival skills. *ASAs and ATPs are considered by the enemy to be prime targets for WMD.*

5-19. Munitions support systems must be structured with the capability and flexibility to continue support operations in an NBC environment. Protective measures and procedures to offset the effects of WMD must be integrated into daily operations. In an NBC environment, frequent testing for contamination of supplies and assets is required. NBC monitoring must be continuous.

NBC CONTAMINATION

5-20. The presence of contamination reduces the effectiveness of munitions unit support. Contamination forces soldiers into IPE that degrades their ability to provide support. Once leaders understand the behavior and characteristics of contamination, they can take measures to avoid and reduce the NBC hazard. Considering these factors enables soldiers, planners, and leaders to integrate NBC defense measures into support and operations plans.

FORMS OF CONTAMINATION

5-21. Different origins and forms of contamination create different types of hazards. To determine risk and method of decontamination, soldiers must understand contamination and what makes it dangerous. See FM 3-5 for more information on forms, types, and persistency of contamination hazards.

NEGLIGIBLE RISK

5-22. Leaders must understand negligible risk levels when making operational decisions. Negligible risk levels for *CB contamination* are those that cause mild incapacitation among no more than 5 percent of unprotected soldiers who operate for 12 continuous hours within one meter of a contaminated surface. Negligible risk levels for *radiological contamination* are measurements of 0.33 cGy or less. This level of radiation causes no more than 2.3 percent mild incapacitation to unprotected soldiers.

DECONTAMINATION CONCEPTS

5-23. Decontamination, or decon, is the removal, destruction, or neutralization of contamination. Leaders must understand the reasons for decon and have a working knowledge of decon principles, types, and techniques. They must be prepared to make an assessment based on the following information:

- Operational situation.
- Available decon resources and METT-TC.
- Effects of decon on unit's ability to perform its mission.

5-24. IPE and collective protection shelters offer only a temporary solution. Decon is the more permanent solution.

5-25. Once a unit is contaminated, there are practical reasons for performing at least some decon as soon as possible. Leaders will follow the guidelines in this section when deciding which actions best support the mission.

DECISION TO DECON

5-26. When making the decision to decontaminate, consider resources available within the context of METT-TC. Before the decision is made, the following factors must be addressed:

- Lethality.
- Performance degradation.
- Equipment limitations.
- Spread of contamination.

Lethality

5-27. Some kinds of contamination are so toxic they can kill or incapacitate within seconds after contact with exposed skin. Should the skin become contaminated, do the following immediately:

1. Stop breathing.
2. Mask.
3. Give the alarm.
4. Decontaminate the skin.

Performance Degradation

5-28. MOPP gear provides protection but degrades performance the longer soldiers are in MOPP. Using tools and weapons or operating equipment while wearing IPE is awkward and dangerous. The protective mask reduces the soldier's field of vision, causing a loss of depth perception. Also, soldiers cannot eat while wearing a protective mask.

5-29. Normal body functions are potentially dangerous in contaminated areas. The simple process of removing IPE to urinate or defecate could expose the soldier to contaminates. The seal on the protective mask or IPE garments may be broken while the soldier is sleeping. Also, wearing of IPE may increase the threat of heat injury. See FM 3-4 for more information.

5-30. Soldier performance decreases over time in MOPP. Leaders must conduct a risk assessment before soldiers in MOPP perform missions. The following tasks are degraded when soldiers are wearing MOPP gear:

- Navigating.
- Terrain orientation.
- Decision-making processes (leader fatigue).
- Communications.
- Maneuver formations.
- Convoy operations.
- Operating MHE.

Limitations of Individual Protective Equipment

5-31. MOPP gear provides protection from CB attacks. Agents can gradually penetrate the protective mask hood. However, the hood's protective qualities can be extended by decontamination. FM 3-4 provides information on filter and MOPP gear exchange and wear limits.

5-32. Leaders must consider time and resources needed to conduct decon versus the degradation caused by operating in MOPP. They must also understand that soldiers must move to a clean area to conduct unmasking procedures. Completion of hasty decon (MOPP gear exchange and vehicle washdown) reduces soldiers' risk based on the following:

- Decreases time soldiers are exposed.
- Provides temporary relief from MOPP.
- Decreases the risk of spreading contamination.

5-33. MOPP gear provides little direct protection from the hazards of radiological (rad) contamination, (i.e., radiation from fallout). However, wearing MOPP gear has indirect advantages. These include preventing inhalation of radioactive particles, keeping contamination off the skin, and greatly simplifying decon. Radiation contamination must be removed as soon as possible, and MOPP gear must be replaced.

Spread of Contamination

5-34. All soldiers must avoid contamination as much as possible. Once a soldier and unit become contaminated, a quick and rapid decon is critical to prevent spreading to a clean surface or area.

PRINCIPLES OF DECON

5-35. The resources of manpower, time, and materiel are critical to the leader's decision on how to sustain operations. Leaders must apply two concepts in the decision-making process:

- Resource usage.
- Ability to sustain operations.

Leaders must know when, where, what, and how to perform decon by following the four principles discussed below.

5-36. ***First, decontaminate as soon as possible.*** This is the most important of the four principles. Contamination hazards force leaders to put the unit into MOPP; this immediately begins to degrade the unit's ability to do its mission. The sooner the contamination is removed, the sooner the unit can reduce MOPP levels and begin restoring the unit's level of support.

5-37. ***Second, decontaminate only what is necessary.*** Decontaminate only what is necessary to continue the mission. This helps sustain combat power. Consider the following factors when deciding whether decontaminating will interfere or help with the mission:

- Mission, "tempo of the battle," and unit munitions support requirements.
- Time available.
- Degree of contamination.
- Length of time unit has been in MOPP.
- Assets available to perform decon procedures.

5-38. ***Third, decontaminate as far forward as possible (limit spread).*** Contaminated soldiers and equipment should not be moved from the operational area if decon assets can be brought forward. This keeps the equipment on location where it is needed, allows decon to begin earlier, and limits the spread of contamination.

5-39. ***Fourth, decontaminate by priority.*** Clean important items of equipment first. Leaders must decide which equipment and supplies are most important to the mission at the time and prioritize them for decon. Since ASAs perform various operations, priorities may be organized by functional area.

LEVELS OF DECONTAMINATION

5-40. The three levels of decontamination are immediate, operational, and thorough (fixed site). Below is a brief description of each level.

5-41. *Immediate decontamination* minimizes casualties, saves lives, and limits the spread of contamination. Immediate decon includes skin decontamination, personal wipedown, and operator spraydown.

5-42. O*perational decontamination* sustains operations and reduces the contact hazard. It also limits the spread of contamination, which may eliminate the need for MOPP gear or reduce the time it must be worn. This process includes vehicle washdown and MOPP gear exchange operations.

5-43. *Thorough decontamination* reduces or eliminates the need for individual protective clothing. Units carry out thorough decon with assistance from chemical units. It includes DTD and DED. See FM 3-5 for information on planning and executing the above levels of decon.

MUNITIONS RESUPPLY

5-44. Munitions units must make every effort to provide uncontaminated munitions to units. Contamination avoidance measures must be emphasized.

If uncontaminated munitions are not available, the available munitions must be decontaminated before they are issued or sent into a clean environment. Munitions support personnel must thoroughly understand decontamination roles and procedures. Because of their units' limited decon capability, available assets must be used effectively. When possible, weathering can reduce contamination to acceptable levels.

5-45. Protective overwraps on munitions containers protect the round in storage, reduce the effects of chemical agents, and make decontamination easier. If munitions are not packaged with protective overwrap, makeshift coverings (i.e., tarpaulins or plastic sheets) provide some protection and speed up decontamination. Protected munitions must be stored on a pallet that can be decontaminated.

5-46. Contaminated stocks are normally not issued, but are kept separate from clean stocks until decontaminated. In emergency situations, certain contaminated items may be issued. Contaminated items are issued only if they provide a decisive tactical advantage. Also, they are issued first to units that are contaminated. *Only under the most extreme conditions are contaminated munitions issued to an uncontaminated unit.* The decision to issue contaminated items is made by the authorized controlling commander. The decision to issue contaminated stocks is based on the following considerations:

- METT-TC.
- Criticality of items.
- Type of contamination.
- Extent of contamination.
- Resources available for decontamination.

5-47. Dealing with contamination means that leaders at all levels must take the initiative and be more innovative than ever before. Essential to the munitions unit's success is its leader's ability to *"read the threat"* and respond accordingly. Munitions leaders must do the following:

- Identify threat locations on the battlefield.
- Identify threat weapons and capabilities.
- Disperse and cover exposed munitions stocks to reduce vulnerability to contamination.
- Update the threat continually using intelligence assets.

5-48. Contaminated munitions must be transported with great care. Coordination must allow for flexibility in routing, marshalling, serializing, and communicating. Vehicles carrying contaminated munitions stocks produce vapor clouds. Vapor clouds are hazardous to the terrain, local population, and follow-on vehicles. The following measures can reduce the hazards of transporting contaminated munitions:

- Limit contamination as much as possible.
- Cover all loads with NBC-protective covers.
- Coordinate movement of contaminated munitions stocks with responsible MCC.

- Designate specific routes as MSRs for contaminated munitions stocks when possible.
- Designate units with collective protection vehicles as the primary contaminated munitions haulers.

UNIT SOPs

5-49. Unit SOPs should be written IAW guidance contained in this chapter and in the following publications:

- AR 190 series (military police).
- AR 380 series (security).
- AR 385 series (safety).
- DA Pam 385 series.
- DO49 Technical Report DPG/TA-88/030. Decontamination of Selected Military Equipment: US Army Ammunition Stocks, September 1988.
- FMs 3-3, 3-3-1, 3-4, 3-4-1, 3-5, 3-7, 3-100.
- TC 3-4-1.

5-50. Command SOPs may be used as format and organization guidelines. At minimum, and in keeping with the mission of munitions support operations, SOPs will address the following areas:

- Dispersal of munitions within the storage area to prevent all of one type munitions from becoming contaminated.
- Contamination avoidance by using ISO containers, military-owned demountable containers, shrink-wrap, CARC paint, NBC-protective covers, pallets, and agent-resistant packaging materials.
- Priorities for protective covers.
- Collective protection for facilities.
- Procedures for identifying and marking contaminated stocks.
- Decontamination of personnel, equipment, MHE, facilities, and munitions.
- Priorities for decontaminating personnel, equipment, MHE, facilities, and munitions.
- Weathering of contaminated stocks.
- Transportation of contaminated munitions.
- Priorities for issuing munitions, including contaminated munitions.

SUMMARY

5-51. This chapter provides only an overview of key considerations for munitions support in an NBC environment. It is not meant to replace current, relative FMs or other guidance provided by the references in paragraph 5-50. An understanding of the NBC threat and establishment of an effective learning program are essential to sustaining munitions support.

Chapter 6

Standard Army Ammunition System-Modernized

This chapter provides information on SAAS-MOD and the environment in which it is used. More detailed information about how to use the system effectively may be found in the Standard Army Ammunition System End User Manual. This on-line manual may be viewed and downloaded at http://www.gcss-army.lee.army.mil/saashdbk/default.htm. Users include commanders, staff personnel, managers/supervisors, and operators.

OVERVIEW

6-1. In the early 1970s, SAAS was developed to provide automated status of ammunition assets for the theater or MACOM (i.e., SAAS level 1). In 1982, SAAS level 3 added Class V management capability and other stock control activities to the corps support command. The two baselines were merged as SAAS 1/3 in 1986. As this system evolved, the requirement to maintain visibility and accountability became more demanding. During Operation Desert Storm, the system was not able to meet wartime requirements. In 1994, SAAS was placed in limited moratorium, and resources were redirected toward developing a modernized system, SAAS-MOD.

6-2. SAAS-MOD replaces and combines SAAS-1/3, SAAS-4, and SAAS-DAO in a modular design concept. It is the approved STAMIS for all Class V conventional retail ammunition inventory control or management. SAAS-MOD automates and integrates ammunition management functions among users, storage sites, and theater managers. It operates on deployable NDI hardware in both tactical and nontactical environments at the theater, corps, ASP, division, and installation levels.

6-3. SAAS-MOD provides total functional integration of existing and future retail level Class V information management systems. SAAS-MOD operates on IBM-compatible PCs using COTS software whenever possible. SAAS-MOD application software handles the unique requirements involved in maintaining ammunition data.

OPERATING ENVIRONMENT

6-4. SAAS-MOD gives commanders and ammunition managers the capability for producing accurate, timely, and near real-time Class V information during peacetime and contingency operations, as well as wartime operations on a highly mobile battlefield. It provides management and stock control for conventional ammunition, GMLR, and C&P materials. SAAS-MOD operates at all of the following functional levels in the theater of operations:

- Corps and theater MMCs or MACOM-equivalent.
- DAO and ATP.
- ASA (TSA, CSA or ASP).
- Installation ASA.

SAAS AREA FUNCTIONS

6-5. SAAS-MOD supports ammunition managers at three functional levels in a theater of operations (MMC, ASP, and DAO) by providing the capability to pass and receive near real-time data. System functions are divided into the following ammunition management areas:

- General core operations.
- Materiel management.
- Requirements management.
- Primary operations.
- Ammunition surveillance management.
- SAAS interface.

These SAAS software areas incorporate distinct functions and processes. Below is an overview of the types of products that can be produced and the types of information that can be processed.

GENERAL CORE OPERATIONS

6-6. General core operations are performed at the three functional levels of SAAS for the system to produce accurate and timely information. They cover establishment and maintenance of the military organizational structure; facility resources; reference data; and ammunition requirements, authorizations, and assets for all functional levels within a theater or corps. These operations are discussed below.

Organization Management

6-7. Organization management incorporates the processes used to identify all activities receiving or providing ammunition support by name, UIC, organization address, DODAAC, and RIC (where applicable). Command and ammunition logistic support structures are also shown.

Security Management

6-8. Security management functions identify valid user(s) by maintaining profiles for each user. These functions are accessed through the Maintain User menu and the User Manager for Domains menu.

Information Support

6-9. Information support procedures provide access to facilities to establish and maintain complete, accurate, and current logistics records. These records facilitate requisition, inventory control, and shipping.

System Administration

6-10. System administrative functions include archiving and restoring data, other file maintenance as needed, maintaining site defaults for MILSTRIP documents, and domain administration.

Maintenance Resources

6-11. Maintenance resource functions include identifying resources needed in the theater to manage ammunition assets. Resource functions also include maintaining the location of all assets, the movement of assets, inventory statistics, and mass transfers.

Accounting Functions

6-12. Accounting functions enable SAAS-MMC managers to establish and maintain the management account structure in the theater. The structure contains recording account codes (detailed accounts), summary account codes, and WARS purpose codes.

6-13. The recording account identifies stockage requirements by DODIC at the ASP for a specific purpose (for instance, a unit, project, or operation). The summary account codes, which are roll-ups of the applicable recording accounts, identify requirements at both the corps and theater levels and relate to a more general purpose. The WARS purpose codes (i.e., war reserve, training, operational projects, and ammunition basic load) identify the total requirements for the theater. The accounting function is used to report requirements for training and ammunition.

MATERIEL MANAGEMENT

6-14. Ammunition materiel management functions are performed only at theater and corps MMCs. These functions relate to the overall management of authorizations, requirements, and redistribution of ammunition assets within the theater. They may be performed at a lower level only when authorized. Material management functions are outlined below.

Identifying Excesses and Shortages

6-15. The processes available for identifying excesses and shortages compare specified theater and corps requirements to available assets (on-hand/in-transit) and display excess and shortage conditions. This function allows direct access requisition or directives processes to order, redistribute, or report excess.

Requisitions

6-16. The available selections allow managers to establish a requisition, create a follow-up transaction, and generate a request for cancellation and/or request modification of a requisition. When a requisition is initiated or modified, the system updates due-in and due-out status.

Directives

6-17. The directives process maintains current due-in and due-out status in the background and contains selections for the following functions:

- Procedures to prepare, view, and update MROs.
- Procedures to prepare, view, and update local shipment directives.
- Procedures to maintain shipment notifications for shipments within or coming into the theater or corps.
- Procedures to initiate and maintain MILSTRIP excess reports and generate shipment directives for the ASP when shipping instructions are received from the CCSS.

Background Processes

6-18. This batch process handles all transactions coming in through the communications process from DAAS, SPBS-R, and any SAAS activity. It routes and processes all MILSTRIP, SAAS, and SPBS-R transactions. Besides updating the SAAS tables, the process creates output for WARS and other SAAS activities.

REQUIREMENTS MANAGEMENT

6-19. The functions of managing ammunition requirements are performed at the DAO and ATP. They include maintaining ammunition requirements and visibility and distribution within the division. The DAO is responsible for distributing ammunition, verifying unit requirements, and tracking ammunition coming into the division. Requirements management functions are described below.

Task Force Support

6-20. Task force support processes allow the manager to create and update task force data for a military organization. These processes also identify ATPs providing support.

Requirements in Wartime Operations

6-21. Management processes in wartime allow the manager to update, submit, and monitor ammunition requirements and to facilitate distribution within the division.

Requirements in Peacetime Operation

6-22. Management processes in peacetime allow the DAO to manage requirements and basic load, operational load, and training ammunition for the division.

PRIMARY OPERATIONS

6-23. Primary operations functions, also called ammunition asset management, are normally performed at the ASP. They are used to receive, store, issue, and account for ammunition in a retail ammunition stock record account. The account may be located at an ammunition DS/GS company or the responsible installation organization. Functions are described below.

Stock Control

6-24. Stock control processes cover all transactions used to maintain and update the stock records and supporting documents of a formal stock record account. The processes available are as follows:

- Stock control monitoring (supply studies, due-in/due-out analysis, and excess).
- Stock control operations (receipts, issues, turn-ins, shipments, inventories, and ammunition maintenance transactions).

Storage Management

6-25. Storage management processes include maintenance of storage site (warehouse) profiles, explosive safety profiles, and compatibility information**.**

AMMUNITION SURVEILLANCE MANAGEMENT

6-26. The on-site ammunition inspectors perform ammunition surveillance management functions. These tasks are associated with acquiring and maintaining the records of ammunition quality and safety at ATPs or ASPs.

SAAS COMMUNICATIONS

6-27. SAAS-MOD receives and transmits data from/to several systems at each functional level. SAAS-MOD uses magnetic media, mail, and communications networks to accomplish all interfaces.

SYSTEM PERFORMANCE

6-28. SAAS-MOD provides a standard ammunition management tool that is capable of the following:

- Maintaining current status of all ammunition within the command ASAs and ATPs.
- Computing complete rounds, days of supply, configured loads, and authorized stockage levels.
- Providing data used by the manager to determine redistribution of assets.
- Supporting Class V logistic estimates based on weapon systems.
- Maintaining data on US and foreign munitions for use in determining Q-D and NEW computations and weapon systems interoperability.
- Supporting surveillance stockpile management.
- Supporting ad hoc query, including data imported and exported to other systems.
- Evaluating and providing distribution history and distribution plan.
- Requisitioning from the NICP if acting as a TAMMC or from a higher node if acting as a CMMC.
- Maintaining and calculating the status of CSR.
- Planning, determining, and forecasting future requirements.
- Maintaining and evaluating consumption of ammunition historical data.
- Computing and determining transportation requirements for movement by type and number of carriers.
- Maintaining asset visibility aboard transport vehicles passing through the system including due-ins and due-outs.

INTERFACES

6-29. SAAS-MOD receives and sends data to several systems. When the communications link is down, operators can input data manually if it is received off-line. All data received by communications is normally batch-processed after the communications portion of the interface is complete. All

SAAS activities within a theater provide data for each other. SAAS-MOD contains the following interfaces:

- WARS receives daily SAAS transactions that affect assets.
- MILSTRIP data received and sent to the CCSS.
- MILSTRIP and MILSTAMP data sent and received through the DAAS.
- FEDLOG provides up-to-date catalog information.
- TAMIS-R provides allocation and authorization data for training ammunition.
- CSSCS interface keeps tactical commanders informed on status of selected ammunition.
- DAMMS-R (TC-AIMS-II) allows the MMCs and ASPs to receive information on in-transit shipments.
- SPBS-R provides on-hand quantities at the unit.
- Corps SAAS interfaces with corps DAMMS-R (TC-AIMS-II) and CSSCS activities.
- ASPs, TSAs, and CSAs providing training ammunition support send training expenditure information to TAMIS-R.
- SAAS-DAO uses SPBS-R and ULLS-S4 to track weapon densities, basic load requirements, and training ammunition support.

REQUIRED HARDWARE

6-30. The NDI hardware required to operate SAAS is purchased through a DOD computer contract that provides complete systems. The user gets the most modern equipment available on the contract at the time of purchase and installation. The equipment is tailored for each of the three functional levels and to the site that operates it. Quantities of hardware at each location are based on unit missions and are outlined in the BOIP for SAAS. The equipment described in this paragraph is subject to change because of improvements in technology.

THEATER/CORPS

6-31. The computer hardware at the theater and corps MMC level consists of a network file server, 1 to 14 PCs for user terminals, 1 to 8 laser printers, a UPS, surge suppressor, LAN equipment, and modems.

DIVISION AMMUNITION OFFICE/AMMUNITION TRANSFER POINT

6-32. The computer hardware at the DAO and ATP levels consists of a network file server, a printer, surge suppressor, laptop for each ATP, LAN equipment, modems, and AIT equipment. AIT equipment includes the following:

- RF interrogator/laser scanner and docking stations.
- Portable printer.
- Thermal printer.

AMMUNITION SUPPLY POINT

6-33. The hardware for the ASP consists of a network file server, a printer, surge suppressor, 3terminals (PCs or laptops with monitor), LAN equipment, modems, and AIT equipment. AIT equipment is the same as listed above.

REQUIRED SOFTWARE

6-34. The SAAS System Administrator Manual can be viewed and downloaded at http://www.gcss-army.lee.army.mil/saashdbk/default.htm. This manual identifies all software required to operate or continue operations in an emergency. See Appendix B of the End User Manual for more information.

CONTINGENCIES

6-35. Several circumstances can disrupt the normal operations of an automated system. The SAAS End User Manual provides courses of action to be considered and/or included in the development of contingency plans. Table 6-1 lists those SAAS-MOD critical functions that must continue to be performed manually in the event of system failure.

Table 6-1. SAAS-MOD Critical Functions

SAAS-MOD CRITICAL FUNCTIONS			
Action	**DAO**	**ASA**	**MMC**
Maintain current status of all ammunition	X	X	X
ID all excess and shortages of ammunition	X	X	X
Maintain reference and catalog information	X	X	X
Maintain communications with interfacing systems	X	X	X
Request ammunition, obtain status/follow-up	X		
Maintain backup of system and data files	X	X	X
Prepare essential ammunition reports	X	X	X
Process/calculate RSR and CSR requirements	X		
Process ammunition issue, turn-in, and receipt transactions	X	X	X
Process ammunition shipment transactions		X	X
Requisition ammunition, obtain status/follow-up		X*	X
Conduct inventories of ammunition, process discrepancies, make adjustments		X	
Report excess and shortages			X
Maintain copies of all documents processed off-line and post them when the system is back on line	X	X	X
Report ammunition requirements to WARS			X
* This action conducted by an independent ASA only.			

PROBLEM REPORTS

6-36. All SAAS-MOD users are responsible for identifying and reporting problems and submitting recommended changes on an ECP-S for software enhancements. Control logs (automated or manual) are maintained by all units submitting problem reports and ECP-S. Submit problem reports using DA Form 5005-R.

SUMMARY

6-37. SAAS-MOD corrected shortcomings of the legacy system and incorporated lessons learned from Operation Desert Storm. The system was developed in incremental blocks: Block 1-A (MMC) and Block 1-B (ASP and DAO). Full system fielding has resulted in the removal of the DAS-3 and TACCS from the SAAS inventory. It is anticipated that all functional applications currently in SAAS-MOD will evolve into the Global Combat Support System-Army.

Chapter 7

Munitions Safety

Historical Perspective

Following the cease-fire in Operation Desert Storm, the US lost more vehicles in one munitions-related accident than it lost to enemy forces during the conflict. This accident occurred when the munitions in one vehicle ignited, and the resulting fire spread to adjacent vehicles that were parked too close together. Many people were injured in the incident, and two soldiers were killed in the cleanup of the site.

Safety is always critical, whether an ammunition unit or platoon is operating in a peacetime, combat, or SASO environment. This chapter focuses on munitions safety. It covers the three levels where safety awareness is most effective. It discusses the Army Safety Program and explores areas of special concern, including the handling, loading, and unloading of munitions; the safe handling of explosives; unexploded ordnance procedures; proper use of tools and MHE; and reports of malfunctions.

SAFETY LEVELS

7-1. All soldiers and leaders must maintain a proactive posture towards safety in day-to-day operations. The need for total commitment to safety should be evident to commanders, senior soldiers, and their subordinates. The importance of safety is intensified for units and personnel engaged in munitions-related activities. Safety awareness is most effective at three levels: command, leader, and individual. These levels and the specific responsibilities of key personnel and individuals are discussed below.

COMMAND

7-2. Commanders are responsible for protecting personnel and equipment under their command. Safety, to include risk assessment and accident reporting, is an inherent responsibility of commanders at all echelons. They must take an active and aggressive leadership role in safety planning and programs. Responsibilities include appointing a safety officer/NCO IAW AR 385-10 and DA Pam 385-1, determining the cause of accidents, and taking necessary preventive and corrective measures. Also, commanders must establish an explosive safety program IAW AR 385-64 and DA Pam 385-64.

7-3. Unit safety officers are appointed on written orders and must complete a safety officer course. They report directly to the commander on safety-related matters and administer the unit safety program. The unit safety officer or NCO accomplishes the following duties:

- Prepares a unit safety program and a field safety SOP focused on awareness (rather than on reactive safety reporting).

- Reviews regulations and TMs and recommends procedures for increasing safety in unit operations, as well as in operations involving receipt, handling, storage, transport, and issue of munitions.
- Recommends procedural changes to the commander that will reduce accident risk, injury, and property loss.
- Organizes a safety committee, if needed, to assist with inspections and the formulation and recommendation of safety procedures.

See AR 385-10 and DA Pam 385-1 for guidance on appointing and functions of unit safety personnel.

LEADER

7-4. Leaders must ensure that soldiers perform their duties safely by taking the following proactive steps:

- Make soldiers aware of hazards through continuous training.
- Stress safety in operations.
- Halt unsafe operations.
- Prevent accidents through planning and preparation.

INDIVIDUAL

7-5. The key to a good safety program, and the focus of the unit safety effort, is to prevent individual soldiers from having accidents. Individual soldiers are responsible for their personal safety. Part of this responsibility includes taking the following actions:

- Becoming familiar with the Army's general safety policies for ammunition and explosives and related operations (see AR 385-64 and DA Pam 385-64).
- Learning the principles of how munitions function, how to handle, store, and transport munitions safely, and how to safely operate MHE.
- Becoming familiar with the hazards and safety precautions that apply to specific munitions.

A relaxed attitude regarding any one of these elements can lead to an accident. A problem with more than one of these elements often leads to disaster. The one who normally knows whether or not all elements are in proper balance is the individual. The safety equation below is important for soldiers to remember.

Training + Equipment + Motivation + Execution with Caution = Safety

RISK ASSESSMENT AND MANAGEMENT

7-6. *Risk assessment* is the identification of hazards and their possible effects. In peacetime, leaders learn to assess risks during training exercises. Techniques learned in peacetime training can be used successfully in combat and SASO. However, after careful evaluation of the mission, a certain amount of risk can be taken in combat and SASO that would be unacceptable in peacetime operations. See DA Pam 385-64.

7-7. During the planning phase of any operation, safety personnel must conduct a task hazard analysis and safety evaluation before writing unit SOPs. This allows sufficient time for safety input to ensure that operational changes can be made efficiently. The basic concerns during hazard analysis are METT-TC, physical layout, and the personnel involved in the operation. Experience has shown that preplanning significantly reduces accident potential and increases efficiency.

7-8. *Risk management* is the decision-making process that balances operational demands against identified risks. Risk assessment and risk management must be fully integrated into operational planning and execution. Risk management is a closed-loop, five-step process that can be used for any type of mission. The five steps are as follows:

- Identify all hazards, including those to soldiers, equipment, and stocks.
- Assess hazards to determine the risks involved and their impact in terms of potential loss and cost. To a degree, assessments are based on probability and severity.
- Develop control measures that eliminate or reduce hazards and risks; continually reevaluate risks until they are reduced to a level where the benefits outweigh costs.
- Implement controls that are effective in eliminating hazards and reducing risks.
- Enforce control measures through supervision and continually evaluate them for effectiveness.

7-9. The proper use of risk assessment and risk management procedures is a primary force protection method. Protecting personnel, equipment, and stocks from damage or loss is the bottom line.

STANDING OPERATING PROCEDURES

7-10. A written SOP must be developed and used for all munitions operations. Procedures must describe the operation so an inexperienced soldier can perform the operation safely. Failure to follow an SOP is a major cause of munitions-related accidents.

7-11. Many publications contain procedures and standards that may be used in developing reliable and useful SOPs for munitions operations. The following publications are among the most applicable:

- US Army Materiel Command regulations, pamphlets, and drawings.
- Army regulations and DA pamphlets.
- Bureau of Explosives publications.
- Code of Federal Regulations.
- Department of Defense Standards.
- Department of Transportation publications.
- Depot maintenance work requirements.

- International Air Transportation Association publications.
- International Atomic Energy Agency publications.
- International Civil Aviation Organization publications.
- International Maritime Dangerous Goods publications.
- Joint and other service regulations.
- Military standards and handbooks.
- Standardization agreements.
- Supply bulletins.
- Technical bulletins and manuals.
- Command guidance and SOPs from higher headquarters.

7-12. Soldiers must have the information necessary to perform their tasks safely. Supervisors are responsible for ensuring that all soldiers involved in an operation or task read the applicable SOP before the operation begins. The SOP must be available at the operations site and will identify potentially hazardous items or conditions that could arise. The unit safety SOP must include the following:

- Safety personnel activities and responsibilities.
- Safety training requirements and training schedule.
- Inspection procedures to detect safety violations, and recommend and enforce corrections.
- First aid training requirements and training schedule.
- Provisions for briefings on new ammunition items and technical intelligence updates.
- Procedures for accident investigations.

MUNITIONS AND EXPLOSIVES STANDARDS

7-13. AR 385-64 establishes munitions and explosives safety standards to protect military personnel, Army civilian employees, the public, and the environment. It is supplemented by DA Pam 385-64. These publications prescribe the Army's general safety policies and standards for munitions, explosives, liquid propellants, and related facilities and activities. They cover the following topics:

- Responsibilities.
- Q-D standards.
- Waiver authority and requests for waivers.
- Exemptions.
- Effects of explosions.
- Permissible exposures.
- Hazard classification.
- Compatibility groups.
- Personnel protection.
- Facilities construction and siting.
- Electrical standards.
- Lightning protection.

- Firefighting.
- Chemical agents and munitions standards.
- Accident reporting relating to the storage, packing, shipping, maintenance, and destruction of munitions.

7-14. Beyond unit SOPs, commanders must ensure that safety regulations and directives or other policies established by higher headquarters are followed during munitions operations.

7-15. Due to the destructive nature of munitions, all responsible personnel, including the user, must be constantly aware of safety procedures. Carelessness, faulty equipment, hazardous working conditions, and unsafe practices may result in injury, loss of life, and property damage. In wartime, these factors may seriously disrupt munitions support and thus have a negative impact on the outcome of operations.

7-16. Concern for the safety of personnel and property is paramount in DOD and DA safety regulations. These regulations prescribe universally applicable standards and practices. They require the preparation and implementation of safety programs, including fire plans (i.e., prevention, protection, and fighting), destruction plans, accident and incident control, and reporting plans.

7-17. Whenever and wherever munitions are handled, stored, or moved, rigid enforcement of safety regulations and strict observance of safety practices is mandatory. The ASCC announces policies and, through the TSC and COSCOM, prescribes safety procedures for munitions in the theater.

MUNITIONS AND EXPLOSIVES HAZARDS

7-18. Many potential hazards are associated with munitions and explosives. These hazards exist in various areas as discussed in the following paragraphs.

OPERATIONS HAZARDS

7-19. All operations involving munitions will be limited to the minimum number of soldiers needed to accomplish the mission safely and efficiently. Tasks not necessary to an operation must be prohibited. Also, personnel not required for an operation will be denied entry to the area. Official visits by safety inspectors and higher headquarters staff must be coordinated through command channels to ensure that personnel limits are not increased during critical operational periods.

7-20. Although some operations can be performed by one individual, at least one additional person must be nearby to watch and assist in an emergency. All operations must be supervised properly to ensure that safety precautions are observed and enforced.

STORAGE HAZARDS

7-21. Munitions and explosives hazards include (but are not limited to) fire, explosion, fragmentation, and contamination. Fire and excessive heat are among the greatest hazards to explosives. Fires in storage areas may be spread by hot fragments from one stack to another or by fire spreading along the ground through combustible materials.

7-22. Storing incompatible munitions together presents another hazard. Appropriate Q-D and compatibility tables in AR 385-64 and DA Pam 385-64, or HN or specific Army theater requirements, will be used to determine which munitions may be stored together. Conforming to these requirements ensures that safe distances are maintained between all munitions. In combat and SASO, peacetime Q-D and compatibility requirements must be followed to the maximum extent possible. Deviation from these requirements must have command approval. Ammunition and explosives under US title, even when stored in or by a host country, are the responsibility of the US commander. Storage must conform to DOD and Army standards unless the use of other criteria is mandated or has been agreed to in an HN agreement.

7-23. Explosive licenses are an important element in safe storage. They are permanent documents developed by authorized safety personnel that may be reissued when storage objectives, METT-TC factors, or Q-D standards change. The responsible safety manager reviews each license annually for compliance and encroachment. The license and maps of the site and surrounding area will be available at both the site and servicing safety office. See Chapter 9 for more information on storage.

HANDLING HAZARDS

7-24. Identification systems assist in identifying specific hazards associated with different types of munitions. Appendix F explains in detail methods for identifying munitions using NSN, DODIC lot numbering, and the color coding system.

7-25. Munitions and explosives must be handled carefully. Any improper, rough, or careless handling may cause them to detonate. These items are safe to handle as long as proper consideration is given to the characteristics of each type of munitions or explosive, how it is assembled, the operation, and normal safety precautions. All soldiers working with munitions must observe the following safety precautions:

- If a hazardous operation is observed, report it immediately to a supervisor. Hazardous operations must be corrected at once.
- Don’t conduct operations without an approved SOP.
- Don’t carry heat- or fire-producing items (matches, lighters, etc.) into a storage area.
- Don’t smoke in a storage location, except in a designated area.
- Ensure munitions are handled *only* by trained soldiers who fully understand the hazards and risks involved. (See AR 385-64, DOD Std 6055.9, DA Pam 385-64 and SB 742-1.)
- Don’t use bale hooks to handle munitions.
- Don’t tumble, drag, drop, throw, roll, or walk on containers of munitions. Containers designed with skids may be pushed or pulled for positioning, unless otherwise marked on the container.
- Don’t tamper, disassemble, or alter any munitions item unless authorized.

- Keep munitions in containers as long as possible to prevent exposure to the elements. This is especially true of items packed in barrier bags or sealed metal containers.
- Open munitions boxes carefully. Return all inner packaging material to the container, and close it to keep out the elements.
- Repack munitions that are opened and not used.
- Don't use familiarity or experience with munitions as an excuse for carelessness.
- Don't carry initiating devices in your pocket. Detonators, initiators, squibs, blasting caps, and other initiating devices must be carried in protective containers. The containers must prevent item-to-item contact. Also, mark the container to identify the contents.
- Ensure that each soldier involved in handling munitions can perform first aid.
- Don't drive nails into shipping or storage containers containing munitions.
- Don't allow waste materials or litter to accumulate in storage areas.
- Be familiar with the location of fire points, the fire plan, and the organization of firefighting crews.
- Handle treated packing material carefully IAW Surgeon General directives and USAEHA Technical Guide 146.

Palletized Munitions

7-26. Before moving palletized/containerized munitions, pallets and containers must be visually inspected for broken banding or for damage to container or pallet. Repair or replace damaged items. Use USAMC unitization drawings to palletize properly. Select the appropriate drawing using AMC DWG 19-48-75-5. Manual handling of munitions, along with banding and strapping, are often necessary during palletizing operations. At minimum, handlers will wear proper protective gloves, safety shoes, and eye protection. If there is not enough space to work safely, the operation will be moved just outside the magazine or storage structure, but no closer than 30 meters to any magazine containing explosives.

WARNING

Banding is extremely sharp and may cause injuries. Such injuries are among the most frequent to occur during palletizing operations.

Electroexplosive Devices

7-27. Electroexplosive devices (i.e., electric blasting caps, squibs, switches, and igniters) are designed to be initiated by electric current. It is possible that such devices may be energized to dangerous levels by outside sources (i.e., static electricity, induced electric currents, radio communications equipment (including commercial cellular phones), high-tension wires, radar, and TV transmitters). It is also possible that induced RF current may cause premature detonation of blasting caps. Therefore, safety precautions must be taken to prevent the premature initiation of all devices.

LIGHTNING HAZARDS

7-28. Protection from lightning is another essential part of protecting soldiers, munitions, and equipment involved in storage operations. For more on protection systems, grounding, bonding, surge protection, testing, and warning systems, see DA Pam 385-64.

STATIC ELECTRICITY HAZARDS

7-29. The generation of static electricity is not in itself a hazard. The hazard arises when the static is allowed to accumulate and discharges a spark in the presence of combustible material, thus providing a source of ignition. This hazard can include sparks discharged from a person. Areas containing combustible dusts, flammable gases or vapors, or ignitable fibers are especially vulnerable to static electricity. Exposed explosives (e.g., primers, initiators, detonators, igniters, tracers, incendiary mixtures, and pyrotechnics) are also sensitive to static electricity. See DA Pam 385-64 for procedures to mitigate static electricity hazards.

TRANSPORTATION HAZARDS

7-30. Transportation hazards include traffic accidents or saboteur incidents. The commander of the shipping unit is responsible for coordinating safe transit. Use DA Pam 385-64 and local policy to develop unit field SOPs. Safety precautions for night operations must receive special emphasis. Several publications dictate procedures for transporting hazardous materials. These include DOD 4500.9-R, 49CFR, TM 38-250**,** and HN regulations. Additionally, TB 9-1300-385 must be checked for suspensions or restrictions before offering ammunition and explosives for shipment. Only school-trained and certified personnel can release shipments of ammunition. Regulations and publications for specific types of shipments are discussed below. See Appendix G for transportation overview, including dimensions and cargo capacities of movement assets.

Rail

7-31. Railcar inspections are a critical part of shipping by rail. Shippers ensure that railcars receive a valid inspection. DOD 4500.9-R, DA Pam 385-64, and 49CFR cover safety inspection criteria, precautions, loading, blocking and bracing, certification of railcars, and spotting of loaded railcars. USAMC load drawings will be followed when loading large items (e.g., MLRS). Refer to AMC DWG 19-48-75-5 for a list of USAMC drawings and ordering instructions.

Motor Vehicles

7-32. Before loading vehicles, ensure that the following actions have been accomplished: all motor vehicles have been inspected, MHE has been load-tested, brakes have been set before loading and unloading, wheels are chocked, and munitions are properly prepared and packaged. DA Pam 385-64 covers safety requirements, inspection criteria, blocking and bracing, loading, placarding, and compatibility. FMs 55-60 and 55-70 cover shipper and carrier responsibilities and placard requirements. See Appendix H for DOT hazardous materials information.

Air

7-33. Aircraft commanders, loadmasters, or crew chiefs supervise the loading and unloading of their aircraft using TM 38-250. A Hazardous Materials Declaration accompanies containers or pallets of munitions on aircraft. AR 95-27, TM 38-250, and DOT regulations cover safety precautions, aircraft specifications, operating standards, loading and unloading procedures, and special handling certification.

Water

7-34. The USCG regulates transportation of explosives and/or ammunition on water under US jurisdiction and in vessels engaged in commercial service.

UNEXPLODED ORDNANCE HAZARDS

7-35. All soldiers must remember that munitions are designed to kill, maim, injure, and destroy. Soldiers must be able to recognize and react to UXO hazards. Reactions include avoiding the hazard, if possible, and marking and reporting it. Under no circumstances will soldiers approach, touch, or pick up UXO items. This rule is valid whether the items are identified as US or enemy. Inexperienced soldiers must be trained to react properly to UXOs.

7-36. If the UXO cannot be avoided, protective measures may be necessary to reduce risk to personnel and to minimize damage to equipment and facilities. All soldiers must be trained on appropriate tasks to ensure that they are not exposed to unacceptable risk.

7-37. Reporting UXOs on the battlefield requires timely and accurate information. The UXO spot report (Figure 7-1, page 7-10) starts with the soldier on the battlefield and moves through command channels so EOD assets can be tasked to respond. It is the initial report by the soldier who found the UXO that supplies the information needed to task resources and prioritize the UXO response. For more information on UXOs, see GTA 9-12-1 and FM 21-16.

EQUIPMENT HAZARDS

7-38. Tools and equipment may pose safety hazards during munitions operations. These hazards can be overcome through awareness training and using well-written SOPs.

Electrical Equipment

7-39. Safety hazards are inherent in electrical equipment. Many munitions are extremely sensitive to electricity. When using electrical equipment, soldiers must follow operating instructions exactly. Only approved electrical equipment will be used. To prevent electrical sparking, all electrical switches, sockets, plugs, and outlets must be of the standard explosion-proof type. Use of electrical equipment in facilities containing explosives must comply with DA Pam 385-64 and the latest edition of NFPA Standard 70.

UXO SPOT REPORT	
LINE 1	DATE/TIME GROUP DISCOVERED
LINE 2	REPORTING ACTIVITY (UIC) LOCATION (GRID)
LINE 3	CONTACT METHOD: RADIO FREQ/CALL SIGN TELEPHONE NUMBER
LINE 4	TYPE OF MUNITION (DROPPED, PROJECTED, PLACED, OR THROWN)
LINE 5	NBC CONTAMINATION
LINE 6	RESOURCES THREATENED
LINE 7	IMPACT ON MISSION
LINE 8	PROTECTIVE MEASURES TAKEN
LINE 9	RECOMMENDED PRIORITY (IMMEDIATE, INDIRECT, MINOR OR NO THREAT)

Figure 7-1. UXO Spot Report Format

Tools and Equipment

7-40. Munitions tools and equipment are designed to be safe when properly maintained and operated. Problems are usually the result of operator misuse or error. Training programs must stress proper use, care, and maintenance of tools and equipment. Supervisors must continually inspect condition and ensure that on-the-spot corrections are made.

7-41. A wide variety of hand tools and equipment is used in munitions maintenance, care, preservation, and storage operations. They range from simple hand tools (i.e., hammers and screwdrivers), to specialized tools (i.e., banding equipment), to tools specifically manufactured to maintain munitions. See TM 43-0001-47 for a listing of this type equipment.

7-42. Hand tools are widely used by munitions soldiers. Only tools made from nonsparking materials (i.e., bronze, lead, beryllium, alloys, K-monel, or polymers) may be used. Specialized materials, such as copper wool and nonflammable solvents, are often used with nonsparking tools. Only properly maintained tools will be used around hazardous concentrations of flammable dust, gases, vapors, or exposed explosives.

7-43. Tools used in the vicinity of hazardous materials must be handled carefully and kept clean. Tools must be checked for damage before and after operations. Tools of lead or beryllium alloys that require sharpening or reshaping may be sharpened only if the area has adequate exhaust ventilation.

NOTE

When ferrous metal tools are used, the immediate area must be free of exposed explosives and combustible materials.

MHE and Lifting Devices

7-44. Lifting devices are used to raise, lower, hold, position, or pull a load from one location to another. Examples are forklifts, cranes, and pallet jacks. MHE is used to store, handle, and move munitions. Examples are forklifts, towing tractors, cranes, pallet jacks, PLS trucks, and conveyors. Forklifts and cranes are the most common MHE used by ammunition units. Operators, supervisors, maintenance, and safety personnel are key to ensuring a safe MHE operating environment. See DA Pam 385-64 for more information.

7-45. **Operators.** MHE and lifting device operators have a limited field of vision when moving a load. For this reason, ground guides are needed when forklifts, cranes, and PLS are in use. Personnel must assume that operators cannot see them and stay clear of the areas where MHE is in operation.

7-46. Size and load limits for MHE must be established and enforced. Operators must understand the danger of exceeding fixed load limits. The following rules will be observed:

- Keep hazardous material moving uniformly through the process steps.
- Minimize rehandling.
- Eliminate heavy manual lifting.
- Reduce transportation distances whenever possible.
- Provide special handling equipment where practicable.

7-47. **Supervisors.** Supervisors must ensure that operators and other personnel comply with the following:

- Inspect forklifts and cranes prior to use.
- Don't use unsafe equipment until needed repairs are made.
- Become thoroughly familiar with the hand and arm signals used to direct MHE and lifting devices (both ground guides and operators).
- Don't move loads that exceed the rated capacity of the forklift or crane.
- Don't strike munitions with the MHE.
- Follow proper lifting procedures. Deviations from lifting procedures must be approved in writing.
- Avoid/stop careless operating procedures.
- When munitions are moved with forklifts, forks must be tilted back and no more than a foot off the ground, except when moving containers with the 50K RTCH. In this case, forks must be raised to a height that offers the operator maximum visibility.
- Don't disconnect safety devices (i.e., dead-man switches).

7-48. **Maintenance personnel.** Maintenance officers are responsible for ensuring that MHE is properly inspected, tested, and maintained, and that only qualified personnel operate this equipment. Other responsibilities include scheduling and documenting equipment tests and initiating and maintaining historical records for each item. Historical records include the following information:

- Nomenclature.
- Identifying markings.
- Acceptance certification (test operator and test director signatures on forms).
- Location.
- Schedule and record periodic inspections.
- Schedule tests and record results.
- Maintenance services schedule.
- Parts replacement record.
- Added identification or safe operation data.

7-49. Upon receipt of new equipment, maintenance personnel inspect the item for a load rating. Every lifting device has a load rating established through testing. The load rating is the maximum authorized load that the device is allowed to lift. The *manufacturer's* rating must never be extended. The manufacturer’s rated load can be found on the equipment capacity data plate or in the operating instructions. See TB 43-0142 for more information.

7-50. Maintenance personnel mark all equipment with the load rating. The only circumstances where markings or tags may be painted over or removed are maintenance, testing, or to change the equipment's rated load.

7-51. Maintenance personnel must conduct maintenance inspections or tests when the equipment is received and at prescribed intervals thereafter. Preventive maintenance is scheduled and performed according to pertinent technical publications.

7-52. Designated personnel perform load tests for all types of cranes and hoists. Weights used can be built locally, or a calibrated load indicator, a dynamometer, or any item of the proper weight may be used. All load-testing devices must have a valid calibration label displayed in a conspicuous place. Attachments, such as slings, chains, and spreader bars, may be tested together. Test loads for forklifts are made using pallet loads that correspond to the manufacturer rated load data and supplemented by factors stated in the vehicle operator’s manual.

7-53. **Safety personnel.** The safety officer must ensure that maintenance inspection or testing programs are in place for all lifting devices, and that the devices are inspected before use. Also, the safety officer must ensure the following:

- Lifting devices that fail inspections and tests are removed from service immediately.
- Operator selection and training programs are effective.
- Load tests are performed after disassembly, overhaul, or replacement of part of the load-bearing system. Perform tests before returning the system to service.

7-54. **Pallet jacks and conveyors.** Pallet jacks and conveyors present special hazards to all personnel and must be handled with care. Personnel will observe the following rules:

- Use conveyors and pallet jacks in areas where they will not create hazards.
- Ensure sectionalized conveyors are supported and sections are interlocked or secure.
- Use conveyor stands to support conveyors so that they remain stable. Don't use boxes or crates of munitions.

ACCIDENT AND INCIDENT CONTROL PLAN

7-55. Every unit that handles or stores munitions must develop plans for controlling accidents and incidents. These plans are part of the command accident/incident control plan, which includes procedures for the following:

- Reporting accidents or incidents.
- Getting assistance from supporting emergency forces.
- Supporting area military and civilian agencies.
- Establishing unit emergency technical escort teams.
- Radiation control.
- Munitions safety control.
- Disarmament.
- Munitions evacuation.
- Unit firefighting teams.
- Unit decontamination teams.

7-56. Training plans, including emergency exercises designed to maintain team efficiency and readiness, are part of the command accident/incident control plan. Such plans encourage personnel assigned to emergency response teams to remain proficient in individual and team duties. Accidents or incidents involving munitions are reported and investigated IAW AR 385-40.

REPORTING MUNITIONS MALFUNCTIONS

7-57. A munitions malfunction is the failure of an item to function as designed when fired, launched, employed, or subjected to functional tests. Malfunctions include abnormal or premature functioning of an item when properly handled, maintained, stored, transported, or deployed. Malfunctions don't include accidents or incidents resulting from negligence, vehicular system accidents, fires, and misuse.

7-58. A munitions malfunction may have been caused by operator error, equipment failure, environmental conditions, or defect in the munitions item. The following steps must be taken to determine the cause of the malfunction:

- User immediately secures the site, equipment, and munitions.
- Commander of the using unit reports all facts through command channels.
- Higher headquarters *may* assemble a team to investigate the incident.
- The operational command *may* suspend from use the munitions or equipment involved, based on METT-TC.

- Investigating team determines cause of the malfunction and provides disposition instructions for the items involved.
- The team provides reports required by higher headquarters IAW AR 75-1.

SUMMARY

7-59. Safety awareness must be a primary concern of all soldiers regardless of rank. While the unit commander and the safety officer/NCO bear the primary responsibility for ensuring that appropriate procedures are in place, supervisors and individual soldiers are responsible for ensuring that these procedures are followed. References cited in this chapter contain more detailed information and must be used to develop SOPs and support an active safety training program.

Chapter 8

Fire Protection, Prevention, and Safety Awareness

This chapter discusses fire protection and prevention programs and procedures. Topics covered include fire divisions, hazard classifications and fire symbols, common safety violations and hazards, and characteristics of munitions fires.

FIRE PROTECTION PROGRAM

8-1. Every Army activity must have a fire protection program that includes fire protection training, fire suppression, and fire prevention. The program's objective is to eliminate the causes of fire and reduce the potential for loss of life, injury, and property damage. This objective is consistent with peacetime, combat, and SASO.

8-2. The commander's awareness and involvement are the most critical components of an effective fire protection program. Preserving life and property is a fundamental duty of all levels of command and supervision.

FIRE PREVENTION COMPONENTS

8-3. Each Army installation must establish a well-planned fire prevention program that includes SOPs, fire prevention training, identification and elimination of hazards, enforcement of fire regulations, and adequate fire protection for facilities. This program requires strong command emphasis and support.

8-4. Frequent surveys and inspections help to establish the best standards and practices for preventing fires. Munitions fires are among the most feared because of the potential for casualties, destruction, and loss of property and equipment. Most fires involving munitions are preventable. Thus, fire safety awareness and training in prevention practices are especially important.

STANDING OPERATING PROCEDURES

8-5. The fire prevention procedures presented here are basic. They should be supplemented by whatever other standards the commander feels are needed to protect the ASA. At minimum, the unit SOP will contain the following rules and procedures to be enforced by everyone working around munitions:

- Strictly regulate and control smoking in areas where ammunition, explosives, highly combustible materials, or flammable items are kept. If smoking can be regulated safely, designate specific locations approved by the commander or safety officer and equip these areas with proper receptacles for butts or smoking residue. Do not allow smoking in vehicles passing through these areas.
- Locate the smoking area at least 50 feet from the area containing munitions and explosives if noncombustible walls do not separate these two areas. Also ensure that at least one serviceable fire extinguisher is placed in the area. Do not permit anyone whose

clothing is contaminated with explosive or hazardous material to use the smoking area.

- Do not permit use of matches or other flame-, heat-, or spark-producing devices in any magazine area or field storage activity. The only exceptions will be by written authority of the commander or safety officer.
- Use only flashlights or storage battery lamps approved by the US Bureau of Mines and listed by the UL or other recognized authority in structures that contain ammunition or explosives.
- Locate overhead transmission and power lines no closer to the storage location than the height of the pole or 50 feet, whichever is greater. If the cable is buried for at least 50 feet from the storage location, existing storage facilities may be modified with underground electrical service.
- Use dry cleaning solvent, not gasoline or other flammable liquids, for cleaning purposes. Ensure that adequate ventilation is available when using solvent. See TB MED-502 for guidance.
- Locate parking areas no closer than 100 feet outside storage areas. Control these areas to reduce fire hazards and provide easy access to firefighters.
- Police areas on a daily basis for combustible materials left over from operations. Stack and/or properly dispose of these materials. See DA Pam 385-64 for stacking guidelines and distance requirements.
- Use nonheat-producing equipment that will not exceed temperatures of 228 degrees.
- Control vegetation or undergrowth with weed killers or by mowing or plowing. Livestock grazing may be used under special, controlled conditions. Remove all cut vegetation and undergrowth. Ensure that weed killers do not contain substances that might spontaneously ignite in hot, dry conditions.
- Carefully consider controlled burning to eliminate vegetation and undergrowth. Allow no burns within 200 feet of any explosive location. Firefighting equipment and personnel will be standing by during these operations.

FIRE PLAN

8-6. Any activity that stores or handles munitions must have an effective safety program and prefire plan to help prevent and fight fires.

8-7. The fire plan serves as a tool for training and for implementing prevention and firefighting rules and procedures. It must cover all munitions areas and possible exposures of munitions to fire. The plan will describe the following:

- Emergency functions of responsible personnel.
- Organization of firefighting teams and alternates.
- Communications and alarm signal activity.
- Responsibilities and emergency functions of outside agencies.

8-8. Details of the plan may vary to suit the individual installation or field activity. It must include training requirements for all personnel and establish the following procedures:

- Reporting the fire.
- Evacuating nonessential personnel.
- Notifying nearby commands and locations of impending dangers.
- Extinguishing or controlling the fire.
- Using communications and alarm signals.
- Controlling the fire until firefighters arrive, and meeting and instructing firefighters on circumstances of the fire (i.e., types of munitions involved and hazards).

The fire plan includes a map that identifies storage locations, the road network, and munitions hazard/hazards at each location (including fire and chemical symbols). See AR 420-90 for additional guidance.

TRAINING

8-9. Training is a vital part of the fire protection and prevention program. All personnel and firefighters involved with munitions must be trained in the precautions and proper methods of fighting fires. Training will include an understanding of individual responsibilities as identified in the fire plan. It must also include instruction in the following:

- A system for reporting fires.
- Procedures for sounding alarms.
- Evacuation procedures.
- Application and meaning of each type of fire and hazard symbol.
- Type and use of appropriate firefighting equipment.

8-10. Fire drills encourage and increase safety awareness and must be conducted at least once every six months. Although fighting munitions fires is the primary responsibility of fire department personnel, munitions personnel must be trained to act quickly and to extinguish and/or control a fire. Every attempt must be made to control or contain a fire to prevent loss of life and reduce injuries, minimize property damage and loss of munitions, and protect mission-essential functions.

8-11. Instructions to supervisors and personnel will include steps that increase fire safety. All supervisors must be thoroughly familiar with fire hazards. They are responsible for ensuring that personnel are trained in alarm procedures and firefighting equipment, and that they know the locations of emergency exits other than the usual doors, gates, or roadways. Emergency exits must be clearly marked with visible exit signs. Personnel will be trained to use these exits automatically in case of fire or other emergency. An unannounced fire drill that involves the response of a fire department must never be conducted without coordinating with the fire chief.

SAFETY VIOLATIONS

8-12. Serious consequences often result from the lack of training or failure to follow instructions and written safety regulations and procedures. The most common safety violations are as follows:

- Smoking.
- Carrying and using matches and other flame- or heat-producing items in forbidden areas.
- Tampering or playing with munitions, particularly grenades, demolition materials, and pyrotechnics.

COMMON HAZARDS

8-13. A fire in the ASA can start in any number of ways. Most often, fires begin in vegetation and accumulated waste materials, wastepaper, scrap lumber, dunnage, broken pallets, and boxes. Causes include the following:

- Unauthorized use of spark-producing tools.
- Use of defective MHE and vehicles.
- Use of faulty or unapproved electrical equipment.
- Failure to provide proper barricades.
- Failure to provide firebreaks/proper firebreaks.
- Use of improper grounding techniques.
- Failure to provide lightning protection systems.

EQUIPMENT AND FIREBREAKS

8-14. A small fire involving ammunition or explosives may rapidly become intense and lead to an explosion. While personnel must not be exposed to the hazards of an imminent explosion, it is vital to attack a small fire at once using authorized equipment and firebreaks.

Fire Extinguishers

8-15. Hand-held portable fire extinguishers can be used to fight small fires. All fire extinguishers must be easily accessible and maintained in good operating condition. See Figure 8-1 for the appropriate extinguishing agent to use for fighting each class of fire.

Type of Fire	Extinguishing Agent
Class A−Combustible (materials such as wood, paper, rubbish, or grass).	Water.
Class B−Volatile flammables (materials such as oil, gasoline, grease, or paint).	Carbon dioxide, halon, foam, or dry chemical.
Class C−Electrical (electrical equipment).	Carbon dioxide, halon, or dry chemical.
Class D−Combustible metals (magnesium potassium and so forth).	Dry powder.

Figure 8-1. Fire Extinguishing Agents

Water Barrels and Sand

8-16. Water barrels and pails, sand boxes, and shovels provide a recognized means of combating Class A fires in ASAs where the combustible material consists primarily of grass, wood, dunnage, boxes, and empty containers. Barrels must be covered to prevent insect breeding and evaporation and will be winterized as necessary. At least two metal pails must be available for each barrel. Water barrels may not be needed if the ASA is located on an installation that meets the following conditions:

- Vegetation control measures are adequate, and the area is monitored regularly.
- A fire plan and an organized firefighting force with the equipment capable of combating grass and brush fires are in place.
- Updated fire maps are maintained at fire stations and storage areas. These maps indicate the location of each storage area and the hazard at each site.
- Storage area work crews are equipped with serviceable extinguishers.

Hand Tools and Other Larger Equipment

8-17. Rakes, shovels, picks, and other equipment needed to fight grass or vegetation fires must be in adequate supply. Also, plows, graders, and bulldozers should be available.

Firebreaks

8-18. Firebreaks may be both artificial and specific. Artificial firebreaks include roads, highways, cleared manmade areas, survey lines, and transmission lines. Specific firebreaks are cut in advance and maintained to prevent the progress of any fire. It may not be possible to cut firebreaks during tactical operations due to METT-TC factors. General guidelines for firebreaks can be found in DA Pam 385-64.

FIRE HAZARDS AND SYMBOLS

8-19. Depending on the materials involved, fires that occur in buildings and magazines containing ammunition and explosives vary in intensity and outcome. Certain explosives ignite on contact with a spark or flame or when subjected to frictional heat or concussion. Some substances burn freely. Others, such as solid or liquid propellants, explode while burning or develop heat so intense that firefighting efforts are nearly futile.

8-20. Firefighters must be well acquainted with the hazards in each fire hazard group. They must know which methods of fighting fires are most effective for the materials under their protection. Also, they must be proficient in using the personnel protective devices needed for fighting various types of fires.

FIRE DIVISIONS AND HAZARD CLASSES

8-21. Ammunition and explosives are separated into fire divisions based on the relative danger they present to firefighters (see Figure 8-2).

Fire Division 1 indicates the greatest hazard, with the hazard decreasing with each ascending number. Fire Divisions 1 through 4 correspond with Hazard Classes 1.1 through 1.4. See DA Pam 385-64 for further discussion of the Hazard Classification System.

8-22. Fire Divisions 1 and 2 include the ammunition and explosives in Hazard Classes 1.1 and 1.2 (excluding nuclear weapons). In a fire, these materials can be expected to detonate with moderate to severe fragmentation hazards. Make no attempt to fight fires involving Division 1 unless a rescue attempt is being made. Attempts to extinguish a Division 2 fire may be made if it is in an early stage, or to fight the fire until the risk becomes too great.

8-23. Fire Division 3 is comparable to Hazard Class 1.3 and presents a mass fire hazard. Personnel in the area will give the alarm and fight the fire if explosives are not directly involved.

8-24. Fire Division 4 consists of ammunition that presents a moderate fire hazard. Fires that involve this type of ammunition will be fought by firefighters with portable and mobile fire-extinguishing equipment until the fire is brought under control. See DA Pam 385-64 for more information on fighting fires.

FIRE DIVISION	HAZARD
1	Mass detonation
2	Explosion with fragments
3	Mass fire
4	Moderate fire

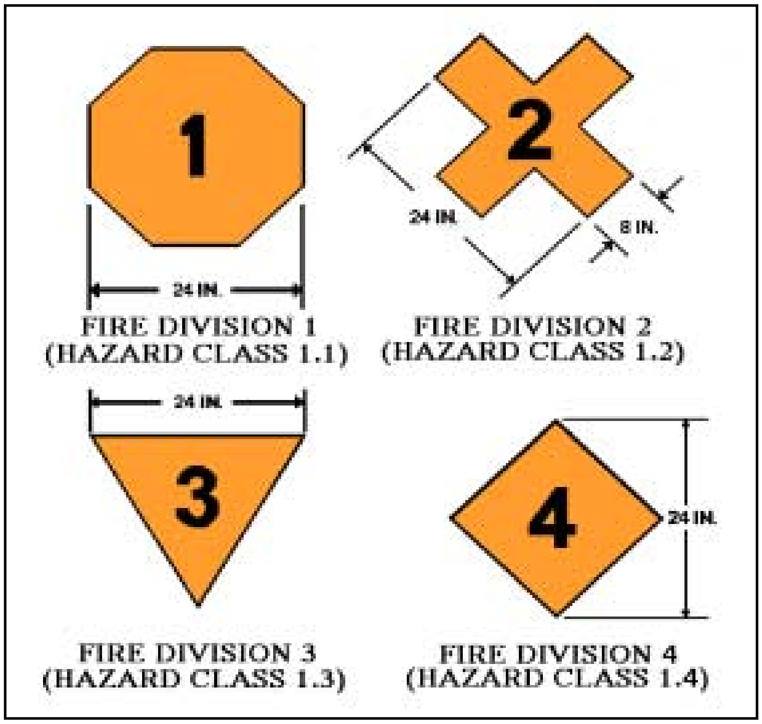
Figure 8-2. Fire Divisions and Hazards

FIRE DIVISION SYMBOLS

8-25. Each fire division is represented by a distinctive fire symbol. The shapes and dimensions for each symbol are identified in Figure 8-3 and Figure 8-4. These symbols enable firefighters to recognize possible hazards as they approach the fire scene. The applicable fire division number is shown on the symbol. To facilitate long-range identification, these symbols have different shapes.

FIRE SYMBOL	SHAPE	NSN
1	Octagon	7690-01-082-0290 7690-01-081-9581
2	Cross	7690-01-082-0289 7690-01 087-7340
3	Inverted triangle	7690-01-081-9583 7690-01-081-9582
4	Diamond	7690-01-081-9584 7690-01-082-6709

Figure 8-3. Fire Symbol Shapes and NSNs



Background: Orange No. 12246 (Fed Std 595A or GSA Catalog).
Numbers: Black No. 170338 (Fed Std 595A or GSA Catalog 10 inches high and 2 inches thick.
NOTE: Small symbols may be used where appropriate. See DA Pam 385-64.

Figure 8-4. Fire Symbols

POSTING SYMBOLS

8-26. The fire symbol that applies to the most hazardous material present will be posted at or near all non-nuclear explosive locations. Backing material for the symbols will be made from a noncombustible material of the same shape. Symbols must be visible from all approach roads. When all munitions within the ASA are covered by one fire symbol, it may be posted at the entry control point.

8-27. When different HC/D of munitions are stored in individual multicubicle bays or module cells, appropriate fire symbols will be posted on each bay or cell. Only one fire symbol is be displayed at the entrance of a row where facilities containing munitions and requiring the same fire symbol are located in a row or on one service road.

8-28. Fire symbols must be placed on entrances to arms rooms that are licensed for holding and storing quantities of explosives. Also, the appropriate fire symbol must be displayed on a locker or similar type container where licensed explosive munitions are stored. However, symbols are not required on the exterior of a building if the building is exempt from Q-D requirements contained in DA Pam 385-64.

Exceptions When Posting Fire Symbols

8-29. It is not required to post fire symbols on locations having 1,000 rounds or less of HC/D 1.4 small arms ammunition (.50 caliber or less). Unless HN symbols differ and, by agreement, HN symbols are required, fire symbols must be used. The ASA commander may remove fire symbols for security purposes. In this case, the commander must emphasize giving prompt and exact information to the firefighters regarding any changes in the status of explosives.

8-30. If vehicles and aircraft are parked in a designated explosives parking area, fire symbols need not be posted providing the area is described in a local SOP or vehicle and/or aircraft parking plan.

8-31. Fire symbols are not required on individual structures used to store, maintain, or handle nuclear weapons or components or on aircraft and/or vehicles loaded with nuclear weapons. See DA Pam 385-64 for more information.

CHEMICAL HAZARDS AND SYMBOLS

8-32. Chemical agent or agent-filled munitions storage and operational facilities must be identified with appropriate hazard symbols as shown in Figure 8-5. The type of hazard symbol selected for this purpose depends not only on the type of chemical agent in the item of ammunition but also on the absence or presence of explosive components in the item.

8-33. Appropriate clothing and equipment are essential when fighting fires involving chemical agents. The protective clothing and apparatus in Figure 8-6 are for firefighting purposes and do not necessarily apply to normal operations. The symbols presented in this figure are described as follows:

- ***Symbol I, Wear Full Protective Clothing.***
  - Set 1. Red rim and figure. Indicates the presence of highly toxic chemical agents that may cause death or serious damage to body functions. Includes the M9 self-contained protective gas mask with applicable hood, or approved equivalent (i.e., M40 series

mask); impermeable suit; hood; gloves; explosives handler's coveralls; and protective footwear, as applicable. A fire blanket should also be available in case of a fire.

- Set 2. Yellow rim and figure. Indicates the presence of harassing agents (riot control agents and smokes). Includes M9 series protective gas mask or self-contained breathing apparatus, explosive handler's coveralls, and protective gloves.
- Set 3. White rim and figure. Indicates the presence of white phosphorus and other spontaneously combustible material. Includes M9 series protective gas mask or self-contained breathing apparatus, flame-resistant coveralls, and flame-resistant gloves.

- ***Symbol 2, Wear Breathing Apparatus.*** Indicates the presence of incendiary and readily flammable chemical agents that present an intense heat hazard. This hazard and sign may be present with any of the other fire or chemical hazards/symbols. Protective masks that prevent the inhalation of smoke from burning incendiary mixture will be used.
- ***Symbol 3, Apply No Water.*** Indicates a dangerous reaction will occur if water is used in an attempt to extinguish the fire. This symbol may be posted together with any of the other hazard symbols.

See DA Pam 385-64 for information on the types of chemical hazards associated with the symbols in this figure. Refer to Table 8-1 to determine clothing and equipment required when dealing with specific chemicals and fillers.

NOTE:
All symbols are 12-inch black letters on 24-inch yellow circle.
Colors Per Federal Standard 595A:
Black No. 17038
Yellow No. 13538

Figure 8-5. Supplemental Chemical Hazard Symbols

1. WEAR FULL PROTECTIVE CLOTHING—

Background in blue.

Figure & rim are:

Red for Set 1 protective clothing.

Yellow for Set 2 protective clothing.

White for Set 3 protective clothing.

2. WEAR BREATHING APPARATUS—

Background in blue.

Figure and rim are white.

3. APPLY NO WATER—

Background in white.

Circle and diagonal line are red.

Figures are black.

Note: Colors per Federal Standard 595A or GSA Catalog
Red No.11105
Blue No. 15102
Yellow No. 13538
White No. 17875
Black No. 17038

Figure 8-6. Protective Clothing and Apparatus

Table 8-1. Chemical Agents/Fillers and Hazard Symbols

Chemical Agents & Fillers in Munitions	Full Protective Clothing			Breathing Apparatus	Apply No Water	G	VX	BZ	H	L
	Set 1	Set 2	Set 3							
GB	X					X				
VX	X						X			
H, HD, HT	X								X	
L	X									X
CL, CG, CK, CN, CNS, CS, BBC, DA, DC, DM, FS, FM		X								
HC				X	X					
BZ		X						X		
WP, PWP			X							
TH, PT				X	X					
IM, NP				X						
TEA, TPA			X		X					
COLORED SMOKES				X						

POSTING SYMBOLS

8-34. When chemical or pyrotechnic munitions are assembled with explosive components, chemical hazard and fire hazard symbols are used together. Chemical munitions without explosive components are identified by chemical hazard symbols only.

8-35. Requirements for posting chemical symbols are similar to those for posting fire symbols. Chemical symbols must be removed, covered, or reversed as soon as chemical agents are removed from a location.

RESPONDING TO MUNITIONS FIRES

8-36. Personnel must take immediate action when fires occur in a munitions area. If fire is discovered in grass or other combustible material surrounding a magazine, structure, or FSU, the following steps must be taken as quickly as possible:

- Sound the alarm.
- Do everything possible, using available firefighting tools, to extinguish or control the fire until firefighters arrive.
- Evacuate nonessential personnel to a well-protected area.

EMERGENCY WITHDRAWAL DISTANCES

8-37. All nonessential personnel must be evacuated to the appropriate emergency withdrawal distance as shown in Table 8-2. The commander is responsible for alerting civilian authorities of any imminent explosive accident that may affect the local community and for providing those authorities with the correct emergency withdrawal distances. See DA Pam 385-64 for more information.

Table 8-2. Minimum Withdrawal Distances

HAZARD CLASS/DIVISION	UNKNOWN QUANTITY NEW	KNOWN QUANTITY NEW
Unknown truck, tractor-trailer and/or facility	4,000 ft (approx .75 mi)	4,000 ft (approx .75 mi)
Unknown railcar	5,000 ft (approx 1 mi)	5,000 ft (approx 1 mi)
HC/D 1.1 (see Note 1)	Same as unknown HC/D above	For transportation use: • 2,500-ft min distance for 500 lb NEW and below. • 5,000-ft min distance for railcars above 500 lb NEW. • 4,000-ft min distance otherwise. • 4,000-ft min distance for bombs and projectiles with caliber 5-in (127mm) or greater. For facilities use: • 2,500-ft min distance for 15,000 lb and below. • 4,000-ft min distance for more than 15,000 and less than 50,000 lb. • Above 50,000 lb, D=105W to the 1/3 power.
HC/D 1.2 (see Note 1)	2,500 ft	2,500 ft
HC/D 1.3 (see Note 2)	600 ft	Twice the IBD with a 600-ft min distance.
HC/D 1.4	300 ft	300 ft

Notes:

1. For HC/D 1.1 and 1.2 items, if known, the maximum range fragments and debris will be thrown (including interaction effects of stacks of items, but excluding lugs, strongbacks, and/or nose and tail plates) may be used instead of minimum range given here.

2. For accidents involving propulsion units, it is not required to specify emergency withdrawal distances based on potential flight ranges of items.

PROCEDURES FOR MUNITIONS-LADEN VEHICLES

8-38. When any part of a vehicle, other than its cargo, catches fire, try to get the vehicle to a clear, isolated area and use a handheld fire extinguisher to fight the fire. Also, ask someone to notify the fire department or engineer firefighting force. Fight the fire until the flames reach the cargo. At that point, evacuate all personnel and equipment to the safe distances listed on DD Form 836. Give firefighters complete information about the cargo as provided on DD Form 836.

SUMMARY

8-39. Fire protection, prevention, and safety awareness during munitions operations is every soldier's responsibility. Commanders are responsible for command and technical supervision of a well-planned, effective fire protection and prevention program at facilities under their command. Supervisors must emphasize quality, routinely schedule training, and ensure that the commander's policies are implemented. Demonstrated performance is the quality control element of an effective fire protection and prevention training program.

Chapter 9

Munitions Storage Procedures

The purpose of field storage in combat and SASO environments is to provide safe munitions storage for tactical units. This chapter contains information on types of munitions storage areas. Also, it discusses planning for and storing of munitions during combat and SASO, with emphasis on meeting safety and storage criteria to the maximum extent possible.

OVERVIEW

9-1. Peacetime explosive standards in DA Pam 385-64 must be followed if possible. However, peacetime standards may not be fully met or maintained because threat level, mission, mobility requirements, and physical condition of facilities vary greatly among theaters of operation. Even with variability in conditions, munitions can be satisfactorily and safely stored in the theater. Regardless of conditions in the theater of operations, a single, basic tenet must be followed; that is, *take all measures possible to minimize risk to personnel, materiel, facilities, and stocks.*

AMMUNITION STORAGE ACTIVITIES

9-2. Unlike permanent ammunition storage areas, munitions assets in a tactical ASA are most often stored on the ground and on unimproved surfaces. Munitions are placed in storage compatibility categories separated from each other by the minimum Q-D. This is based on NEW; NEQ; or total gross tonnage per individual storage unit, depending on the storage system selected. Munitions are likely to be stored in one of four types of field storage areas: TSA, CSA, ASP, or ATP. The different types of tactical ASA compatibility categories, Q-D standards, storage systems, and storage planning procedures are discussed later in this chapter.

THEATER STORAGE AREA

9-3. The TSA is located within the COMMZ in the theater's rear AO. The modular ammunition company's HLPs generally operate the TSA. These platoons may receive added support from MLPs. The TSA is usually the largest ASA in the TO. Its mission is to receive, store, and ship containerized and break-bulk munitions. It also issues, inspects, configures, manages and maintains theater reserve munitions. The TSA also provides area ammunition support to units operating in the COMMZ.

9-4. To facilitate shipment, TSAs are located where there is direct access to airfields, railheads, ports, road networks, and facilities. If this is not feasible, the TSA should be located within a short line-haul distance of such facilities. The TSA can be either a fixed, semifixed, or open outdoor storage area, or a combination of these.

9-5. In peacetime, the TSA may be a permanent storage facility (e.g., igloo, magazine, bunker, or other fixed or semifixed explosives storage building). Unless the TO has existing fixed explosives storage facilities, the TSA is usually an open outdoor storage area in SASO/wartime.

9-6. The area selected for the TSA should have as much hard surface as possible. Also, it must have adequate drainage and a road network capable of supporting heavy vehicle traffic. It should be designed to move break-bulk and containerized munitions onto and off of railcars, line-haul vehicles, and PLS. Other logistical units (i.e., transportation and terminal support) may be available to assist munitions units in conducting railhead and other transload operations.

9-7. A TSA may expand to about 40 square kilometers to meet its stockage objective (see Table 9-1). If the stockage objective exceeds 25,000 STs, a second TSA should be established. The ASCC and METT-TC determine the stockage objective of TSAs. The TSA receives 100 percent of its stockage objective from the POD.

Table 9-1. ASA Types

ASA	Days of Supply	Stockage Objective
TSA	30 Days	25,000 STs
CSA	7 Days	25,000 STs
ASP	3 Days	NA

9-8. Munitions arrive at the TSA on theater transportation assets. They are usually containerized but may include break-bulk or a combination of both. Because a high percentage of TSA receipts are containerized, munitions and transportation personnel must manage containers to guarantee accountability and to retrograde them for reuse. See FM 9-6 for a discussion of the flow of munitions in the theater of operations.

CORPS STORAGE AREA

9-9. The CSA is located in the corps rear AO. The modular ammunition company's MLPs generally operate the CSA. If the CSA is receiving containerized munitions, HLPs may support the MLPs. The CSA mission is to receive, store, issue, inspect, configure, manage, and maintain the corps reserve munitions stocks.

9-10. The CSA supports the munitions requirements of all assigned or attached corps units. It is also the primary source for the division's munitions. It stocks 10 to 15 DOS to meet initial combat requirements; thereafter, it maintains about 7 DOS. At least one CSA is required to support ASP and ATP operations for each committed division. The CSA may be fixed, semi-fixed, or open storage depending on the tactical situation. It is more fixed than the forward storage areas it supports. Usually in SASO or wartime environments, it consists of open storage.

9-11. The CSA should be located near MSRs and railheads to allow easy access for theater and corps transportation assets. The site must have an improved road that can handle heavy vehicle traffic.

9-12. The CSA receives about 50 percent of its munitions from the POD and 50 percent from the TSA. These munitions may be in either break-bulk or containerized loads. Munitions shipped from the CSA to an ASP may be in single-DODIC, break-bulk, or configured loads. Munitions shipped from the CSA to the ATPs are in MCLs.

9-13. The CSA can expand to about 40 square kilometers. When the stockage objective reaches 25,000 STs, a second CSA should be established. The COSCOM establishes the CSA stockage objective, which is based on projected theater combat rates and METT-TC.

9-14. The COSCOM ordnance/corps support battalion analyzes workload requirements and synchronizes operations with corps transportation assets. See FM 9-6 for a discussion of the flow of munitions in the theater of operations.

AMMUNITION SUPPLY POINT

9-15. The ASP is another source of munitions for the division. It is located in the division's rear AO. The modular ammunition company's MLPs operate the ASP. The ASP provides munitions support to corps and nondivisional units in the division's AO.

9-16. The ASP normally stores 3 DOS to meet routine, surge, and emergency requirements of supported units. Tactical plans, availability of munitions, and the threat to resupply operations are the basis for stockage levels.

9-17. ASPs should be considered as temporary, open storage sites. ASPs are located near MSRs and rails (if feasible) to allow easy access for theater and corps transportation assets. It is essential that ASPs have good road networks that can support heavy vehicle traffic. Thus, commanders will focus on locations that minimize the need for engineer support. The ASP receives 100 percent of its munitions shipments from the CSA on flatracks in single, mixed DODIC, or configured loads.

AMMUNITION TRANSFER POINT

9-18. The ATP is a temporary site from which munitions are transferred from corps transportation assets to the organic vehicles of the big six combat units (i.e., armor, aviation, infantry, artillery, air defense artillery, and combat engineers.) The DAO controls all division ATPs.

9-19. Each maneuver brigade has an FSB that operates an ATP in the BSA. The ammunition sections of the following units operate the ATPs:

- Supply company, FSB in a heavy or light division.
- S&T company, support battalion in a separate brigade.

They support all units in the brigade support sector and receive mission guidance from the DAO. Their mission is critical since they logistically support the maneuver commander's tactical plan to ensure that munitions are available for combat.

9-20. The MLP (ATP section) of the modular ammunition company operates an ATP located in the DSA of the division AO. It supports corps, divisional, and nondivisional units operating within the division support AO. The DAO provides mission guidance to the ATP and establishes its priorities.

9-21. Using either unit vehicles with MHE (e.g., HEMTT), PLS, or organic ATP MHE, munitions are transferred from corps trailers or PLS flatracks to vehicles organic to the using unit. Departing empty tractors/PLS vehicles backhaul the empty trailers and flatracks. Corps transportation should always drop a trailer or flatrack and take one in return. This practice is called *one-for-one exchange* and also applies to using units, tactical situation permitting. Without this exchange, a shortage of trailers and flatracks occurs that may critically impact resupply of munitions. S&P trailers or flatracks are also used for retrograde of unserviceable munitions and CEA. Also, these vehicles may transport fatalities and POWs, if necessary. See FM 55-10 for more information.

9-22. Shipments from the CSA and ASP together make up 100 percent of the ATP stockage level. About 75 percent of the ATP munitions requirements are throughput from the CSA in MCLs. The other 25 percent are received from the supporting ASP in single, mixed DODIC, or configured loads.

9-23. The ATP is located near an MSR or adequate road network to provide access for corps transportation assets and combat user vehicles. The ATP must be on firm ground with good drainage and offer easy access for vehicles. Also, it must allow for easy recovery of pallets, S&P trailers, and PLS flatracks.

9-24. The site must be large enough to allow MHE to maneuver. Flatracks and trailers must be placed so the MHE has adequate space to transfer munitions. As with any other tactical site, good cover and concealment are extremely important. See Chapter 4 of this manual for a complete description of ATP organizational structure and munitions operations and procedures.

STORAGE SAFETY PRINCIPLES

9-25. The highest degree of safety in munitions storage will be achieved if each item is stored separately. However, this is not feasible. Observing the following principles will ensure safety of munitions storage regardless of the type of facility:

- Balance safety, environmental, and other factors when storing a mix of munitions. Certain munitions must not be stored together.
- Do not store munitions and explosives with dissimilar materiel or items that present positive hazards to the munitions. Examples include flammable or combustible materiel, acids, or corrosives.
- If compatible, different types of munitions and explosives may be mixed in storage.
- Mix compatible munitions and explosives in storage when such mixing facilitates safe operations and promotes overall storage efficiency.

- Do not store munitions with an assembled initiating device as they present a significant storage risk. Exceptions include–
  - If the device is packaged in a manner that eliminates risk of accidental detonation.
  - If fuzed items are configured/packaged to prevent arming of the item.
  - If safety features prevent accidental initiation or detonation of the item.
- Protect munitions from the elements by providing appropriate dunnage and adequate shelter and ventilation. This practice reduces maintenance and ensures maximum serviceability and shelf life of stocks.
- Place munitions in appropriate SCG or FSC and separate by minimum Q-D as determined by DA Pam 385-64.

COMPATIBILITY

9-26. All munitions and explosives are assigned to an appropriate SCG for storage at Army activities. See Appendix I for more on SCGs.

9-27. During wartime and contingencies, logistical considerations and combat situations may warrant more risk-taking. When warranted, the MACOM commander may authorize relaxation of storage compatibility requirements. The FSCs listed below simplify field storage compatibility while maintaining an appreciable safety level. Compatibility requirements do not apply when storing configured loads in the theater of operation. Another safety element, Q-D classification, further separates munitions and explosives into hazard classes.

FIELD STORAGE CATEGORIES

9-28. For storage in the field, munitions are segregated into primary groups referred to as storage categories. Groupings are based on the desirability to store components of complete rounds in adjacent stacks and consideration of the hazards of propagation of explosion, range of fragments, spread of fires, and chemical contamination.

9-29. Listed below are the FSCs of conventional ammunition. (See DA Pam 385-64 for more information on field storage.)

- *Category A.* Fixed and semifixed artillery munitions, except incendiary and chemical.
- *Category B.* Propelling charges, fuzes, primers, flash reducers, and separate loading artillery projectiles, including HE and AP but not incendiary and chemical projectiles.
- *Category C.* Mortar ammunition and hand grenades, except incendiary and chemical.
- *Category D.* All pyrotechnics and chemical ammunition, including chemical-filled rockets; gas, smoke, and incendiary bombs; gas and smoke artillery ammunition; incendiary and chemical grenades; smoke pots; VX-filled mines; bulk-packed incendiary and small arms tracer cartridges.

- *Category E*. All demolition explosives, antitank and antipersonnel mines (except VX-loaded), and components (i.e., blasting caps, firing devices, detonating cord, and safety fuses).
- *Category F*. Rockets, rocket motors, and rifle grenades, except chemical.
- *Category G*. The following items of USAF Class V supply: all unfuzed HE bombs, aircraft mines, aircraft torpedoes, and fragmentation bombs; fuzes and/or primer-detonators for the above items; fragmentation bomb clusters, fuzed and unfuzed. The remainder of USAF Class V items must be stored in other applicable categories.

QUANTITY-DISTANCE

9-30. Q-D hazard classifications are designed to protect personnel and property in areas adjacent to storage facilities, to limit the quantity of stocks that may be lost in an explosion, and to reduce the possibility of any explosion involving large quantities of explosives and munitions.

9-31. Q-D relationships for specific classes of munitions and explosives are based on levels of risk considered acceptable for that item. During peacetime, the Q-D tables set forth in Chapter 5 of DA Pam 385-64 must be strictly followed unless a waiver is obtained. The tables apply generally to exposures involving nonmilitary personnel, family housing, and health and morale facilities.

9-32. During SASO, contingency, and wartime operations, military requirements may make full compliance with safety regulations difficult. Compliance with Q-D regulations is of great importance to commanders since their purpose is to minimize losses of personnel and stocks and to maintain the full operational capability of facilities. Normal explosives safety criteria, procedures, Q-D separations, and methods of application in DA Pam 385-64 apply except where waivers are granted.

9-33. To meet readiness requirements, certain units may have their ABL uploaded on organic vehicles or stored near the unit in a BLAHA. DA Pam 385-64 defines Q-D requirements. BLAHAs outside and inside the US have different standards, which must meet the Q-D standards of this publication.

9-34. Applicable Q-D terms for field storage safety purposes include the following:

- *Storage subdivisions*. Field storage areas are divided into storage sections and further subdivided into FSUs and stacks to ensure adequate dispersion for operational safety purposes.
- *Dispersion*. If assets are adequately dispersed, the ASP is not an inviting target from the air. When possible, quantities of each type of ammunition should be stored in two or three widely separated sections. If the contents of one section are destroyed, the entire supply of any one item will not be lost. When space is not sufficient to disperse the ammunition, construct earthen barricades to help reduce the hazard.
- *Barricades*. The effect of sympathetic detonation can be reduced using man-made barricades constructed IAW DA Pam 385-64.

- *Interstack distance.* Interstack distance is the minimum distance between the near edge of adjacent stacks. Stacks are required to be separated by minimum distance of 50 feet to inhibit the spread of fire. However, be aware that interstack distances do not always provide protection from propagation of detonation by blast overpressure or missile fragments. Aggressive fire fighting usually helps to prevent the spread of fire from one stack to another at this distance. The greater the distance between stacks, the less likely fire will spread from stack to stack. When possible, separate stacks by a distance greater than that prescribed.
- *Inter-FSU distance.* The inter-FSU distance, which is the distance between the nearest edge of the nearest stacks in adjacent FSUs, can also help prevent the spread of fire (see Table 15-2 of DA Pam 385-64). When these distances cannot be met, use extra care in setting up and maintaining fire protection, fire guards, and firefighting measures.
- *Optimum safety distance.* The optimum safety distance is the limit inside which structural damage from a blast or missile fragments will be serious. Consider this distance if ASAs, ATPs, or BLAHAs have to be located near gasoline or other storage facilities, hospitals, permanent radio transmitters, railroads, and highways.

9-35. Special storage requirements must be met for certain categories of munitions. Safety and environmental considerations make it essential to comply with the following guidelines:

- *Nontoxic Chemical Ammunition.* Store chemical-filled ammunition so that each container, item, or bomb can be inspected and easily removed. Keep projectiles containing phosphorus out of the direct sun and store them bases down. Locate water-filled barrels for immersing leakers within the toxic ammunition site.
- *Toxic Chemical Ammunition.* Store toxic chemical ammunition in the part of the ASP with the lowest elevation and at least 1 mile downwind from inhabited ASP buildings or other storage areas. Make sure no inhabited buildings or storage areas are within 2 miles downwind of the storage site. Also, ensure maximum security for this type area.
- *Rockets.* Safety requirements for storing rockets are stricter than for most other types of conventional munitions. Store small- and large-caliber rockets and large-caliber, free-flight rockets on the outer edge of any storage area. Point the noses away from all other stored munitions and away from all inhabited areas. Locate the rockets so that only their own containers are between the rockets and the barrier. Do not make stacks more than one row deep.
- *Bombs.* Category G ammunition (bombs) is usually stored and issued by the USAF. In emergencies, however, depot and ASP commanders may store bombs. For this reason, it is important to be aware of the following restrictions:
  - The FSU is the smallest storage unit authorized.

- Fuzed fragmentation bombs in the same FSU may not be stored with other bombs.
- Components of bombs (i.e., fins, fuzes, primer-detonators) can be stored between FSUs. If that is done, remember to protect fuzes and primer-detonators from heat and moisture.

SITE SELECTION

9-36. Safety and efficiency must be top priorities when selecting a field storage site. Site selection and layout of an ATP are discussed in Chapter 4 of this manual. It is essential that explosives experts be involved early in this process to preclude possible future disruptive, safety-driven relocations of established Class V facilities.

9-37. A primary and an alternate site should be selected. Alternate sites provide relocation options in case the primary site is unavailable for operational reasons, or if enemy action or the effects of weather on the terrain make evacuation necessary.

9-38. A map and ground reconnaissance of the proposed sites should be made. Reconnaissance ensures that the sites are suitable for performing safe operations and providing efficient support to using units. A map recon provides information on the terrain and the possibility of natural cover and concealment. A ground recon supports the information gathered from the map recon and further reveals terrain features. Also, it reveals other conditions that may have changed or may not be identifiable on a map.

9-39. Based on reconnaissance information, site recommendations are submitted to higher headquarters for approval. The sites selected may not be approved for operational and/or tactical reasons. The selection process may have to be repeated, or higher headquarters may identify an area for the location of the storage area. See Appendix J for information on FARPs.

ASSESSING TACTICAL REQUIREMENTS

9-40. Tactical conditions and METT-TC factors must be reviewed to reduce conflict between the tactical and safety requirements of an ideal site. Often, these requirements are not compatible, and defense risks must be weighed against the operational mission.

9-41. The tactical situation may require that procedures be modified or supplemented. Other tactical considerations are found in FM 71-100 and FM 100-15. The following considerations apply to all storage and supply sites:

- *Transportation*. Sites should be located near the MSR and supported units to allow easy access. The distance to supported units must be reduced in keeping with security constraints.
- *Facilities*. Sites should have ready access to (but be located as far as possible from) hospitals, important military installations, airfields, docks, factories, fuel storage and/or distribution activities, and similar facilities. This is especially true for sites subject to enemy attacks. If chemical munitions are stored, downwind distances to populated areas must be considered.

- *Defense.* Sites should be easy to defend against ground attack using the fewest personnel and materials possible. The site must be large enough to allow for dispersion of stocks to protect against heavy loss by fire or explosion. As with any other tactical site, good cover and concealment are critical.
- *Road network*. In addition to access and exit roads, sites must contain a good internal road network. Roads must easily allow large vehicle passage under all weather conditions and should require as little maintenance as possible. A one-way traffic pattern is preferred to minimize confusion and congestion.
- *Railhead*. Sites with potential for expansion into larger, more permanent sites should have a railhead nearby.
- *Terrain*. Sites will be established on firm, level ground. Drainage patterns and soil conditions must be studied carefully. A level site that does not drain adequately during wet weather may result in unsafe and inefficient operations. The site must provide easy access for using unit vehicles and for recovery of PLS flatracks, pallets, and trailers. Natural barriers at proper intervals are desirable to segregate field FSUs and categories of munitions.
- *Fire safety*. The site must be inspected for fire hazards. A low level of flammable vegetation and an adequate water supply are favorable considerations.

STORAGE SYSTEMS

9-42. Once the site has been selected and approved, the selection of a munitions storage system must be made. Four storage systems may be used for field storage of munitions and explosives:

- Area storage.
- Roadside storage.
- Combination area/roadside storage.
- Modular storage.

9-43. Consider the following factors when choosing a storage system:

- Physical characteristics of the site.
- Location of hostile forces.
- Weather expectations for area.
- Time and resources available.
- Expected life of the site.
- Available space and type of operation that most readily comply with Q-D requirements.
- Freedom of vehicle movement throughout the storage site. Vehicles must be able to pass other vehicles being loaded/unloaded. There should be no dead-end roads that require backing up or turning around.
- Roads should be improved, if possible, to withstand traffic up to fully loaded trailers and PLS trucks.

Area Storage System

9-44. The area storage system is divided into three sections and subdivided into FSUs and stacks. Stacks of munitions are arranged in a checkerboard pattern and spaced according to the Q-D requirements in DA Pam 385-64. This system provides efficient use of the total area, but may require significant road and pad construction and stabilization of earth.

Roadside Storage

9-45. Roadside storage allows munitions to be stored in stacks along the edges of existing roadways. FSUs and sections are spaced according to Q-D requirements in AR 385-64. Effective use of this method requires a larger road network and more total area than the area storage system. However, little construction is necessary.

9-46. A variation of roadside storage, known as *"storage in depth,"* is very useful if the existing road network is limited. With this method, one or more additional stacks of ammunition is stored behind the roadside stack, away from the road. The use of this system is restricted in wet climates or in areas with poor soil conditions or heavy forests. Under those conditions, the stacks of ammunition would be difficult to reach.

Area and Roadside Storage

9-47. A combination of area and roadside storage is often used to lessen the bad aspects of both systems. It allows the most effective use of the existing road network in a limited area. While this combination does not require as much land as roadside storage, it does involve some road and pad construction.

Modular Storage System

9-48. The modular storage system is used for storage of high-explosive bombs and other conventional ammunition. Munitions are stored on pads within earth-barricaded areas called cells. The cells are joined to form modules, which may, in turn, be arranged to form module blocks. See DA Pam 385-64 for modular storage system requirements.

9-49. The modular storage system is used in a combat zone where limited security and inadequate real estate/operational limitations make it impossible to store munitions IAW Q-D and compatibility regulations for area, roadside, or area/roadside storage. It may be the only solution for storing large quantities in rear areas where there is insufficient real estate.

9-50. This system does not provide the same degree of protection for personnel or munitions stocks afforded by regular Q-D dispersion. Before deciding to use the modular system, compare its advantages and disadvantages to those of the other field storage systems as defined in DA Pam 385-64.

9-51. DA Pam 385-64 contains information on where, when, and how to use the modular storage system. Also, it discusses physical and construction characteristics, explosives limitations, barricade requirements, and site selection criteria.

9-52. **Special Guidelines for Modular Storage.** In peacetime, modular storage is limited to HE bombs (fuzed or unfuzed, with or without fins), similarly cased HD 1.1 ammunition (e.g., HE projectiles), and the following contained in nonflammable or metal shipping containers: 30mm and smaller ammunition, cluster bomb units, inert munitions components, and HD 1.4 munitions. By design, modular storage can redirect some of the blast overpressure from an explosion but provides little to no protection against fragment debris or the spread of fire. In a combat zone, there are no restrictions on the type of ammunition authorized for modular storage. In this case, mixing ammunition in modular storage is authorized.

9-53. Certain munitions require special storage consideration when stored in a modular system. Ensure safe storage by complying with the following guidelines:

- All storage and safety considerations will be followed for CS and CN (riot control agents) chemical munitions and WP/PWP ammunition. Cells containing these items must be in a separate module, away from other types of ammunition.
- Chemical munitions (except WP/PWP and CS/CN) and rockets will be stored in end cells of modules. Store rockets and missiles pointing into barricades.
- Blasting caps can be stored in a separate bunker built inside the cell containing all other compatible munitions. Ensure the bunker has adequate side/overhead cover to protect other explosives in the cell.
- Propellant charges must be stored in a separate module. The module may have one or more cells, depending on the required stockage.
- ICM must be stored alone in a separate module. The module may have one or more cells, based on the required stock objective.
- Munitions and CEA awaiting destruction must be stored in a separate module. The module may have one or more cells, based on requirements.

Urban/Built-up Areas

9-54. Structures in urban or built-up areas may also be used to temporarily store or protect munitions. The possibility of setting up an ASA in a village or other built-up area may be realistic and requires consideration when planning wartime operations. With this system, the real estate could be in an existing small city, a village, or a structure in the outlying countryside. The physical configuration layout is based on the safety requirements for munitions storage found in DA Pam 385-64.

STORAGE AREA PLANNING

9-55. After the site has been selected and the system of storage is known, a storage plan and SOPs must be written for the operation. Good planning helps ensure that operations are safe and efficient. The following checklist will be used when developing the storage plan/concept of operations:

- What is the expected maximum tonnage of each SCG?
- What are the expected average daily receipts and issues?

- How much time is available before the first munitions shipment arrives?
- What is the expected lifetime of the storage area?
- Which storage system will be used?
- What physical characteristics of the terrain can be used as natural barricades? What characteristics deny or restrict use of certain areas?
- What natural cover and concealment are available?
- What engineer construction and support are available or necessary?
- What is the total stockage objective for the site?
- What special security requirements are needed for classified and sensitive items based on the CIIC? See the FEDLOG or JHCS for a detailed explanation of CIICs and the CIIC for any munitions item.
- What section, FSU, and stack numbering system are needed to ensure that location and retrieval of stocks are fast and accurate?

GENERAL LAYOUT

9-56. Fundamental rules apply to the layout of all types of munitions supply and storage facilities. General safety procedures must be considered first in any site layout. Basic operating procedures are also very similar. Munitions survivability software is being developed by the Army and should be available in the near future. This software is designed to assist the user in preparing the safest storage plan possible for the designated terrain.

9-57. Key differences between CSA/TSA field sites and ASP/ATP sites are that the CSA and TSA generally have larger, more stable storage areas and better road networks.

9-58. All storage areas should be arranged into separate sections to enhance safety. The arrangement of stocks in each section should make receipt, issue, and inventory/rewarehousing/configuration as easy as possible.

9-59. Each section consists of a number of storage locations or modules, depending on the type of storage system used. Storage locations within each section are separated according to the Q-D requirements in DA Pam 385-64, METT-TC permitting.

9-60. The following guidelines should be observed to maintain efficient operations and prevent units from unnecessary waiting:

- Ensure signs are posted showing traffic direction, entrances, and exits.
- Draw maps of storage areas and provide copies to using units.
- Ensure there is enough dunnage near storage locations.
- Arrange for one-way traffic whenever possible; when not possible, provide turn-around points. Also ensure adequate space for vehicle holding and assembly areas.
- Ensure the use of ground guides is strictly enforced.

TACTICAL LAYOUT

9-61. Layout requirements for each site vary according to the tactical situation, the terrain, the proximity to forward areas, and the type and amount of materiel handled. A good layout is one that achieves the following:

- Provides for easy, efficient work flow.
- Minimizes movement of munitions, tools, and equipment.
- Permits easy entry and exit for heavy traffic.
- Provides effective control of unit operations.
- Permits defense of the area.

Proper positioning of weapons, construction of defensive works and obstacles, and organization of unit defense and security are other prime considerations.

9-62. A map overlay will be prepared to include the defense plan and operational layout for the new area. If needed, a route overlay will also be prepared. The advance, main, and rear parties use overlays, and copies must be submitted to higher headquarters. When HNS is available, the layout will incorporate coordination of services between US and HNS activities. See Figure 9-1 for a typical ASP layout.

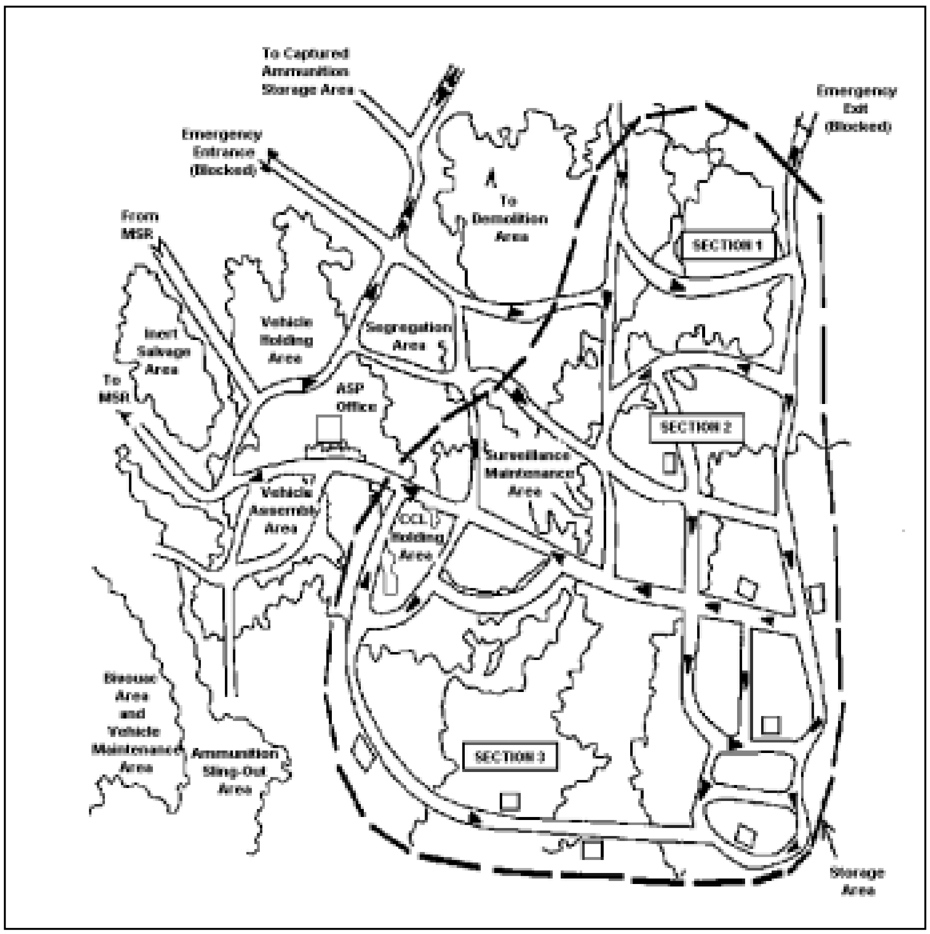


Figure 9-1. Typical ASP Layout Plan

AREA LAYOUT

9-63. The *operations office* is the nerve center of a storage activity. It is normally the control section of an ordnance company or modular platoon. It should be located inside the main entrance where all incoming customers can reach it easily. Also, it should be located near the administrative section but a safe distance from the main ASA. Vehicle holding areas for inbound munitions shipments and vehicle assembly areas for outbound munitions vehicles will be within walking distance. The operations office must have adequate parking for customer and ordnance company vehicles.

9-64. Parking for inbound, ammunition-laden vehicles or unit vehicles scheduled for loading is provided in the *vehicle holding area*. It must have enough maneuver room for large vehicles, and its size must be sufficient to accommodate the largest convoy of vehicles that the site may expect to receive. It is a transit area, and vehicles remain only long enough to be processed for storage or issue.

9-65. The *segregation area* is a temporary storage area for segregating ammunition turn-ins and mixed munitions shipments. It must be located near the salvage area to allow convenient storage or usage of packing materials.

9-66. Nonexplosive munitions, such as munitions residue and salvage materiel, are stored in the *inert salvage area*. It should be located near the segregation area and the surveillance and maintenance area.

9-67. The *demolition area* is set aside for the destruction of unserviceable munitions. A good access road is necessary to facilitate the delivery and unloading of munitions. Because S&P trailers and rough-terrain forklifts may be needed to conduct demolition operations, both the road network and the area must be able to support these vehicles. Land selected for the demolition area will not be used for other purposes. Also, it will have scarce vegetation to minimize the fire hazard. Demolition operations are to be conducted only after munitions disposition instructions have been received from higher headquarters.

9-68. The *vehicle assembly area* provides parking for all outbound vehicles, including empty/loaded ammunition vehicles being assembled into a convoy. The assembly area must be within walking distance of the operations office and meet all requirements of the vehicle holding area.

9-69. Emergency aerial resupply operations are conducted at the *sling-load operations area*. It will be located at least 1,800 feet or 550 meters from munitions storage locations, working areas, and inhabited areas. When planning sling-load operations, the allowable gross weight for cargo aircraft must be considered. See FM 10-450-3, and TM 38-250, for more information on sling load operations.

9-70. The *bivouac area* is the living area for personnel operating the site. It must be located nearby but outside the fragmentation and blast areas. When locating this site, personnel safety distances from the ASA and the physical security of the bivouac area will be the primary considerations.

9-71. Unit vehicles and MHE are maintained in the *maintenance area*. A separate section within this area may be designated for refueling vehicles.

9-72. The *surveillance and maintenance area* is used for performing munitions inspection, repack, and maintenance. For efficiency, it should be located between the operations office and the storage areas.

9-73. Live munitions are stored in the a*mmunition storage area*.

9-74. The *captured enemy ammunition area* is used to store all CEA turned into the storage facility. CEA is always stored separately; once identified and classified, it is stored using the same principles required for storing US munitions.

SPECIAL LAYOUT

9-75. *Munitions stacks* should be positioned far enough off the road to allow trucks to be loaded or unloaded without interfering with traffic. Containers must be stacked so that munitions markings are visible and all containers can be accessed easily. Munitions stacked on an inadequate or unstable foundation may topple or sag. Inspectors should look for settling or shifting stacks so that corrections can be made before damage results. See DA Pam 385-64 for more information.

9-76. Some units use a *standard identification system* to identify and locate munitions. Such systems use lettered or numbered locations that always contain certain types of munitions. For example: Sub-depots are designated by letter; storage sections by number; FSUs by letter; and stacks by number (i.e., munitions may be stored in sub-depot A, section 1, FSU-A, stack 1 [A1A1]).

9-77. Whenever a site is established and similar stocks are required, they are placed in the same relative locations; however, ground features may preclude this. When a standard identification system is used, a major road or prominent landmark may be referenced. If a road or landmark is not available, the system should follow a logical alphabetical or numerical progression as personnel enter and move through a specific section of the site.

9-78. *Lot number separation* divides and stores all munitions by lot number. The manufacturer numbers and identifies munitions by lot. The lot number is vital for accountability, issue, and storage. Ensure individual lots are segregated in each storage location, clearly separated from other lots.

9-79. *Climatic considerations* such as adequate shelter, dunnage, good drainage, and good ventilation are necessary to protect stored munitions. Tarpaulins can be used to protect munitions stacks from the effects of rain and intense sunlight. Tarps must never be placed directly on ammunition; doing this raises the temperature underneath the tarp. Ensure a minimum 18-inch clearance between the tarp and the munitions. Tarps can be used as improvised shelters for VT fuzes and pyrotechnics. Cotton tarpaulins, 16 feet by 16 feet, NSN 8340-00-817-2126, provide both shade and cover.

9-80. In desert and tropical climates, munitions must be shielded from the direct rays of the sun. To minimize exposure to sunlight, position containers with long axes pointed in an east-west direction. Priority for shade is as follows:

1. Guided missiles and rockets.
2. Propelling charges.
3. Fuzes.
4. Pyrotechnics.
5. Projectiles.

When containers are used for storage, doors may be left open or opened periodically so that air can circulate. Blowing sand should not accumulate around containers or pallets.

9-81. The proper use of *dunnage* increases stack stability. Generally, stacks must be at least 4 to 6 inches off the ground to prevent munitions from getting wet and to ensure adequate circulation. Empty munitions boxes or ration boxes filled with sand or dirt may be used to elevate the stacks if lumber is not available. Dunnage must be checked frequently for rotting and deterioration. See DA Pam 385-64 for more information.

9-82. If *drainage* threatens to be a problem, ditches must be dug around stacks of munitions. If propellant charges are stacked, lids will be turned down slightly so water does not seep in or accumulate.

9-83. *Storage of guided missiles and rockets* requires special care. Guided missile assemblies should be stored in permanent structures because the missile bodies have delicate electronic components that must be protected. If stored in the open, protect the containers with tarps or other suitable cover. In either case, storage areas should have hard, level surfaces, and all humidity indicators must be accessible. Guided missiles and rockets must be stored on the perimeter of any storage location, with all nose ends pointing in the safest direction, normally outward.

9-84. Security is a major concern when handling classified or sensitive missile and rocket components. Classified or sensitive components must not be stored with unclassified components. Guards and access control must be employed if these components are stored in the open. An accurate check must be kept on personnel who enter classified or sensitive storage areas or structures. See AR 190-11 for more detailed security information.

9-85. Natural cover and concealment must be used whenever possible to *camouflage* munitions storage areas. Camouflage requirements may conflict with requirements for firebreaks and munitions shelter. The use of camouflage must be consistent with explosive safety and munitions storage procedures. See FM 20-3 for general information on the use of camouflage.

9-86. MHE is essential to the receipt, storage, issue, and maintenance of munitions. The type of MHE available must be considered when planning operations. Certain MHE may not be suited to the terrain. See FM 9-6 for information on MHE assigned to ordnance units.

UNSERVICEABLE MUNITIONS STORAGE

9-87. Unserviceable munitions are those either manufactured with defects or made unserviceable by improper storage, handling, packaging, or transportation. Shipments of munitions received from other supply facilities will be inspected for serviceability. Unit turn-ins not inspected at the time of receipt must be stored in a segregated area for later inspection. Ammunition specialists must be trained to recognize indications of unserviceability and report them. Refer to Figure 3-2 of this manual for information on turn-in procedures.

9-88. Inspectors segregate unserviceable munitions from serviceable munitions for safety reasons and to reduce rehandling. The munitions must be segregated by DODIC and lot number, followed by serviceability classification. Munitions that cannot be positively identified by lot number are automatically classified as unserviceable. Exceptions may be made based on the type, quantity, and condition of the munitions and METT-TC.

9-89. Safety precautions and principles that apply to storage of serviceable munitions also apply to storage of unserviceable munitions. Proper records must be kept on all unserviceable items stored at a supply facility.

9-90. Munitions that require maintenance must be segregated and marked to prevent issue. While minor preservation and packaging are performed at field locations, extensive maintenance is usually performed at a depot storage facility.

9-91. The unit performs the packaging and preservation functions if that is all that is required (see Chapter 10). Time permitting, reparable unserviceable munitions are retrograded for repair.

9-92. Munitions abandoned by using units are treated as unserviceable until inspected. The procedures that apply to unit turn-ins also apply to abandoned munitions. Unserviceable munitions are reported through proper channels for disposition instructions. Unserviceable munitions must be disposed of as quickly as possible to preclude further deterioration and potentially unsafe conditions. DA Pam 738-750 provides guidance in requesting disposition of unserviceable munitions. Hazardous unserviceable munitions are reported immediately through proper channels to EOD detachments for destruction. A demolition area is designated and cleared for the safe destruction of munitions.

SUSPENDED AMMUNITION STORAGE

9-93. Specific lots of munitions and components are withdrawn from issue when they are determined to be unsafe or otherwise defective. The problem may be the result of a manufacturing defect, a firing malfunction, or the deterioration of components. Storing munitions by lot number enables the rapid withdrawal from issue of those items that are unsafe, defective, or suspected of being defective.

9-94. The authority to suspend any lot of conventional munitions is vested in the commander, OSC. However, the installation or area commander may place a local suspension on a suspect lot of munitions. A preliminary report and a later detailed report are forwarded through the supporting MMC to theater army headquarters. The munitions remain in local suspension unless higher headquarters changes its status. (See AR 75-1 for instructions for preparing suspension reports. Suspended lots of conventional munitions and components are listed in TB 9-1300-385. Additional notices of suspensions or restrictions are by QANET updates to ASIS or by other electronic message formats as supplemental changes to TB 9-1300-385.)

9-95. Unless the suspension notice orders it, munitions lots that are stored and later placed under suspension need not be moved to a segregated area. However, stacks of suspended munitions must be clearly marked on all sides using DD Form 1575 and DA Form 3782, or facsimile-formatted documents (taped to the materiel), to show that the items have been suspended or restricted from issue. When foreign nationals are employed, bilingual tags should be produced locally. Suspended or restricted-issue items returned by the firing units, or items received from other supply facilities, must be segregated upon receipt.

CAPTURED ENEMY AMMUNITION STORAGE

9-96. Enemy ammunition is considered excess. IAW AR 381-26, one of three options must be taken when munitions are determined to be excess on the battlefield. These options are use, destroy, or secure and retrograde.

9-97. When an enemy munitions cache is secured for storage, it is first inspected to determine condition, type, and caliber. It is then analyzed and identified by EOD, QASAS/qualified military inspector, and technical intelligence specialists to ensure that it is safe to transport or retrograde to a rear storage area. Items of special interest are noted and quickly reported through intelligence channels. Hazardous enemy munitions must be segregated and disposed of.

9-98. If the cache is retrograded, corps munitions managers are notified to provide QA/QC personnel and transportation assets to support the retrograde operation. These personnel go to the cache to load and transport it to the designated ASA. QA/QC personnel assist in segregating and loading the munitions. The designated ASA places the cache into a designated secure area. CEA must not be stored with US munitions. If possible, it will be stored IBD from all other munitions. Information on the NEW or foreign munitions can be obtained from military intelligence elements. See Chapter 12 of this manual for more information on CEA.

SALVAGE AND PACKAGING STORAGE

9-99. Salvage material includes such items as boxes, crates, and steel containers. Packaging material includes nose plugs, grommets, metal links, clips, cartridge cases, and brass.

9-100. Based on METT-TC, salvage material is normally collected at ASAs and shipped to designated points within the theater of operations for reuse or retrograde. However, if salvage material is turned in at the ATP, the ATP NCO arranges to have it backhauled to an ASA via available transportation. Some salvage material may be used at field facilities to repack serviceable munitions and components. Salvage material is inspected for explosives, recorded on stock records, and reported to the MMC as directed by higher headquarters. The MMC receives disposition and shipping instructions, and gives the instructions to the storage facility based on these reports.

9-101. When inert salvage material is shipped from any munitions facility, the senior inspector must certify the shipment to be free of explosives. Empty chemical containers, boxes, and packaging material must be certified to be free of chemicals or chemical residue.

BINARY CHEMICAL MUNITIONS

9-102. When BCMs are deployed to a theater of operations, the theater commander directs their primary storage location. In wartime, effective measures must be implemented to maintain strict control and safe handling of BCMs. When in-transit, the nonlethal-component canisters are stored separately until higher headquarters gives the release order. Separate storage is imperative for the safety of personnel and facilities. Also, it prevents the possibility of a lethal accident or incident that the enemy could consider as first use.

9-103. BCMs must not be assembled until higher headquarters gives a properly authenticated release order. From the CSA, BCM components are *normally* shipped forward for assembly at the ASP. Depending on the tactical situation, the assembled BCMs are uploaded for issue at the ASP or transported to the ATP for issue. The tactical situation may dictate that the munitions be assembled at the CSA and shipped directly to the ATP. Also, under emergency conditions, unassembled BCMs may be issued directly to the firing unit. Ideally, assembly of BCMs should occur as far forward as possible. This minimizes handling and exposure to possible leaks and contamination. Procedures for storing, shipping, handling, and securing BCMs are discussed below.

Storing and Shipping

9-104. Storage considerations for BCMs apply to both CSA and ASP operations. Commanders of conventional ammunition companies must be prepared to assume custody of BCMs. Normally, the CSA receives BCMs directly from the port and ships these components forward for assembly at the ASP. The commander must ensure that the nonlethal-component canisters are stored in separate structures within the same storage area or in separate locations at different storage areas. Storage of BCMs must be IAW Q-D requirements in DA Pam 385-64. During convoy operations from the port to the CSA, and from the CSA to the ASP, the components are shipped on separate vehicles within the same convoy.

9-105. Upon receipt of an authenticated release order, units generally pick up their allocated BCMs at the same time they replenish their conventional munitions. If the tactical situation changes and uploaded or issued BCMs are no longer required, the units must return the BCMs to the supporting ASA. Munitions specialists disassemble the BCMs and place the component parts in their original packages. The components are then returned to a secure storage location. If there is any uncertainty about the disposition of BCMs, instructions must be requested from higher headquarters.

Handling

9-106. The fewest number of personnel possible must handle BCMs. Commanders must ensure that their units establish SOPs that provide special handling procedures for BCMs. These procedures must emphasize safety and, at a minimum, must include the following:

- Chain of custody.
- Required MOPP gear.
- Required chemical detector kits and alarms.
- Emergency procedures and assistance for accidents and incidents.
- Monitoring and surveillance requirements.
- Inspection requirements for BCMs and related chemical operations.
- Disassembly procedures for assembled BCMs.
- Specific area for assembly and disassembly operations.

9-107. When handling unitary munitions (e.g., CEA), the conventional ammunition unit takes all necessary NBC precautions, especially if there has been an accident. These precautions include dressing in MOPP-4 gear and requesting EOD and chemical unit support from corps headquarters. See FM 9-20 for more information.

Securing

9-108. Generally, physical security principles that apply during peacetime apply during wartime. However, in emergency situations or intense combat conditions some peacetime requirements may have to be waived. Regardless of the degree of combat, commanders must ensure that qualified personnel provide physical security whenever and wherever chemical munitions are handled. From the time BCMs enter the theater, commanders are responsible for their security during handling, moving, and storage operations. Security personnel may include a combination of escort personnel, MPs, conventional ammunition personnel, and designated personnel from the combat user. Security personnel have the primary mission of preventing unauthorized or uncontrolled access to chemical munitions. Unit commanders must develop a detailed unit SOP that deals with the security of these munitions while in their custody. At a minimum, the SOP will include the following:

- Personnel qualifications for those guarding and having access to chemical munitions.
- Identification of authorized personnel.
- Security during transport of munitions. Details for security planning for chemical munitions are given in AR 50-6, AR 190-11, AR 190-14, AR 190-59, AR 380-67, and FM 19-30.

REWAREHOUSING MUNITIONS

9-109. Rewarehousing is the art of using available space efficiently to support receipt, storage, and issue of munitions with a minimum amount of handling. Space layout planning is one of the most important elements of rewarehousing. Consolidation, location, control, and conservation of storage space are key to good rewarehousing.

NIGHT OPERATIONS

9-110. During combat, ammunition units must be able to perform night operations. With the added disadvantage of darkness, safety must be paramount in the completion of all issues, turn-ins, receipts, retrograde operations, and shipments. Factors and considerations that affect night operations include the following:

- Soldiers work slower in darkness. Allow more time than usual during night operations.
- A larger work force is necessary for night operations.
- Emphasis on accountability increases. Ensure that soldiers serving as checkers are familiar with the area layout and the locations of the stocks.
- Safety must be stressed to all individuals involved, especially MHE operators. Additional ground guides are needed for night operations.
- Based on the tactical situation, commanders must decide how much light discipline must be maintained. Ensure that proper batteries and blackout filters are available for lights.
- Use night-vision goggles as much as possible. Ensure that proper maintenance is performed to keep them operational.

SUMMARY

9-111. This chapter focuses on storage of munitions in combat/SASO environments. In the future, it is likely that munitions units will be deployed consistently for SASO where field storage conditions are prevalent. If deployed into a combat environment, a unit's storage requirements and considerations will be consistent with those identified in this chapter. Units that support either SASO or combat operations from a CONUS installation should consult DA Pam 385-64 for peacetime and wartime requirements.

Chapter 10

Munitions Maintenance and Surveillance Operations

Munitions maintenance encompasses all actions necessary to ensure that stocks are either serviceable, or that unserviceable stocks are restored to serviceable condition or disposed of properly. Maintenance responsibilities are assigned to ammunition units based on the unit's primary mission and the availability of skilled personnel, time, tools, equipment, and supplies. This chapter discusses maintenance and surveillance operations, procedures, and functions.

MAINTENANCE PLANNING

10-1. Munitions maintenance planning must be aligned closely with the operational needs of supported units. Maintenance planners must be realistic when considering the availability of supplies and maintenance resources. A reduction in munitions maintenance increases the amount of ammunition taken from the supply system. Conversely, the inability of the supply system to replace unserviceable munitions requires a greater maintenance effort. Proper maintenance, storage, and handling of munitions enhance readiness, reduce replacement requirements, and conserve resources. The maintenance planner must recognize the interdependence of maintenance and munitions support.

MAINTENANCE OPERATIONS

10-2. Units need a constant supply of serviceable munitions. Munitions maintenance is a vital task that must be performed to sustain readiness. Maintenance includes everything from minor packaging and preservation operations (i.e., cleaning, removing rust and corrosion, repairing boxes and crates) to major operations (i.e., complete renovation). Provisions must be made to conduct as much maintenance as possible at the storage location. In some cases, munitions must be retrograded for maintenance. Since the movement of munitions requires transportation and personnel assets, it is inefficient to adopt a maintenance program geared totally to evacuation.

10-3. DS, GS, and modular ammunition units assume a more active role in conducting maintenance operations when operating in the corps and theater areas during combat or SASO. The primary focus in hostile, forward locations is issue and receipt activities; therefore, maintenance may be limited to packaging and preservation.

CATEGORIES

10-4. Munitions maintenance is divided into four categories: organizational, direct support, general support, and depot. Generally, Army munitions personnel only perform the first three categories of maintenance.

Organizational

10-5. All activities that have munitions on hand perform organizational maintenance (generally packaging and preservation) to prevent deterioration from rough handling and exposure. Organizational maintenance in the using unit is usually performed with the technical assistance of ammunition units.

Direct Support

10-6. DS conventional ammunition companies in the theater of operations perform limited DS maintenance and surveillance of stocks under their control. Limits are defined by the capability of the unit and METT-TC. Besides packaging and preservation, DS maintenance may include replacing readily removable external parts and components; these include fuzes of artillery and mortar munitions, propelling charges and primed cartridge cases for semifixed and mortar munitions, grommets, and nose plugs. Maintenance at the DS level is largely due to turned-in munitions.

General Support

10-7. Conventional ammunition companies in the theater of operations that have GS capabilities perform maintenance above the DS level. Modular companies are designed with the capability to perform both DS and GS maintenance. GS maintenance includes, but is not limited to, the following:

- Removal of extensive rust/corrosion; painting and stenciling of Class V materiel; and fabrication of or major repairs to boxes, containers, and crates.
- Replacement of internal/external components that requires the use of operational shields or barricades.
- Demilitarization of ammunition, when directed.

10-8. All DS and GS companies with storage and issue missions are equipped to perform maintenance functions. The tools, equipment, and supplies needed to support maintenance at that particular level are included in each unit's supply and equipment list.

Depot

10-9. Depots perform more complicated maintenance (such as modification, explosive component replacement, or complete renovation) of munitions that are packaged and/or evacuated.

CARE AND PRESERVATION

10-10. Care and preservation are terms often used to describe munitions maintenance at the organizational or DS level. Care stresses protection, and preservation stresses maintenance but includes protection. Care and preservation of munitions are essential for ensuring that stocks are available for combat missions.

10-11. Munitions returned by units can be held in the segregation area for up to 180 days. There, they are identified and segregated by type and lot number, checked for hazardous and nonstandard conditions, and repacked or palletized. Q-D, explosive, and personnel limits must comply with DA PAM 385-64.

10-12. Care and preservation lines may be established, if METT-TC and capability permit, where loose or opened munitions are visually inspected and properly identified. Containers are inspected to ensure that the contents match the information on the outside. Contents are inspected for serviceability, incompatibility, and hazardous conditions. Precautions must be taken when handling depleted uranium items (see TB 9-1300-278). Serviceable items are palletized. Unserviceable but salvageable items are sent for repair. Disposition instructions must be requested for suspended and nonrepairable items. Scrap material is placed in suitable containers and sent to a salvage area.

10-13. If inspection results in the need to repair or replace a container, the contents must be removed unless a new stencil or marking is all that is necessary. Munitions are returned to the container with enough filler material to allow a tight fit. Stencils or markings identical to the originals are placed on the new container. Seals and bands are replaced, and the container is ready for the palletizing area.

10-14. Munitions must be palletized IAW proper USAMC drawings and appendices. Some drawings may be designated as DARCOM drawings. No more than one lot is permitted on any one pallet in storage. Once inspected, pallets are transferred to a storage or shipping area.

10-15. If an explosive hazard exists, the destruction of unserviceable munitions and packaging is carried out only by, or under the supervision of, EOD personnel. Disposition instructions must be requested from higher headquarters prior to destruction. See DA PAM 385-64, DA Pam 738-750, and TM 9-1375-213-12 for more information.

STANDING OPERATING PROCEDURES

10-16. All maintenance operations are performed IAW an approved maintenance SOP. TM 9-1300-250 contains guidelines for preparing maintenance SOPs and organizing maintenance activities. When local nationals are involved in maintenance operations, the SOP is written in their language as well as in English.

SURVEILLANCE OPERATIONS

10-17. Munitions surveillance is the observation, inspection, and classification of munitions and their components for movement, storage, and maintenance. It includes the inspection of all equipment, facilities, and operations. Surveillance activities are conducted by all theater activities that store, maintain, dispose of, or ship ammunition and its components. Surveillance ends only when munitions are expended or destroyed.

10-18. The TSC is normally responsible for general supervision of munitions surveillance in the theater. The COSCOM is responsible for supervision within the corps. The ordnance battalion and CSB or CSG supervise this function in their commands. In established theaters, surveillance activities are under the control of DAC QASAS who are assigned to the appropriate

Army headquarters IAW AR 702-6 and AR 740-1. In theater ammunition units, surveillance is performed by attached civilians and assigned military inspectors.

10-19. Battalion commanders must administer a quality assurance ammunition surveillance program that covers all munitions operations in their command. The QASAS in charge is responsible for this program and reports directly to the commander. Since the training required for the QASAS is more extensive than that of the military inspector, QASAS personnel perform most functional tests and the more complicated inspections. They certify the results of inspections and tests performed by the military inspectors. Some inspection results and functional test reports are signed only by a QASAS. Surveillance in an immature or developing theater is performed by 55Bs in a DS, GS, or modular ammunition company. Early deployment of QASAS personnel will ensure full surveillance capabilities.

SURVEILLANCE FUNCTIONS

10-20. Munitions inspectors are responsible for ensuring the reliability and serviceability of munitions. They perform their mission in plants, depots, storage areas, and on the battlefield. The surveillance mission encompasses the following duties:

- Inspecting storage facilities, field storage, and all types of storage sites to ensure compliance with storage standards.
- Inspecting surrounding areas for fire hazards and other nonstandard conditions.
- Checking for conditions that could speed up deterioration of items in storage.
- Teaching surveillance and munitions safety.
- Preparing and maintaining records and reports to cover all surveillance activities. (Surveillance records and reports are contained in SB 742-1.)
- Observing, inspecting, and investigating munitions and components for serviceability.
- Monitoring storage, handling, and maintenance operations and recommending changes to enhance safety and operational effectiveness.
- Recommending controls needed to maintain standards.
- Advising the commander on munitions surveillance matters.
- Inspecting munitions to determine quality, safety, and deterioration.
- Maintaining munitions drawings and specifications files and indexes.
- Maintaining munitions suspension files.
- Inspecting incoming and outgoing munitions shipments for compliance with existing instructions and regulations.
- Furnishing technical advice to the commander and supported units on munitions safety and compliance with munitions regulations.
- Ensuring that surveillance functions are performed according to SB 742-1 and applicable TMs and SBs.

10-21. Munitions inspectors provide an invaluable service to the commander and supported units. Inspectors assist in many activities including the following:

- Investigating ammunition malfunctions and accidents.
- Inspecting and testing lightning protection systems.
- Conducting unit basic load inspections.
- Preparing waivers for storage facilities.
- Planning construction of storage facilities.
- Planning field storage areas.
- Monitoring uploading/downloading of ammunition to/from combat vehicles.

10-22. Ammunition inspectors also help to plan, administer, and enforce the explosives safety program. This program includes the review, evaluation, and inspection of operations, procedures, equipment, and facilities used with munitions and explosives operations.

SURVEILLANCE INSPECTIONS

10-23. An active surveillance inspection program is vital to ensuring munitions reliability. IAW SB 742-1, the following surveillance inspections are performed by QASAS and military inspectors:

- Receipt, including depot transfers, field returns, and CEA.
- Periodic (cyclic).
- Storage monitoring.
- Special.
- Pre-issue.
- Verification.
- Munitions condition code.
- Ammunition in the custody of units.

Serviceability Standards

10-24. The purpose of an inspection is to find deterioration and determine the serviceability of items. The inspector must be familiar with all information on the items, including components and packaging, as well as the characteristics of the weapons in which they are used. Serviceability standards are contained in SB 742-1.

10-25. Inspection procedures include observation, tests (such as gauging or strength tests), and functional tests. As a rule, munitions must not have defects that alter their characteristics, make them unsafe, or prevent them from performing as designed. The inspector must determine if defects can be corrected and at what maintenance level it must be done. Serviceability is not assumed from the fact that the item can be fired in the weapon for which it was designed. It must function correctly when fired.

10-26. The prime enemies of munitions are heat, moisture, and rough handling. Deterioration is faster when moisture is combined with a rise in temperature. Inspectors must look for indications of moisture, rust, or corrosion on projectiles and fuzes; corrosion and cracks on cartridge cases; deterioration of propellants; loose closing caps; and moisture or dampness inside containers.

Physical Defect Standards

10-27. Evaluating materiel that shows deterioration or damage is a decision based on the training, experience, and judgment of the inspector. Deterioration of materiel in storage is natural and varies depending on protective coating, packaging, and storage conditions. Deterioration is progressive. If maintenance is not performed, it progresses from an incidental stage, to minor, to major, and possibly to a critical stage. These four categories of deterioration are used to establish a uniform system of examination for deterioration or damage.

10-28. Further guidance on classifying metal, plastic, and rubber component deterioration; mixed ammunition; damaged packaging; and placing defects into one of the four defect categories can be found in SB 742-1 and other applicable SBs and TMs.

Guided Missile and Large Rocket Inspection

10-29. GMLR munitions, components, propellants (liquid and solid), protective clothing, packaging, and packing materials are inspected and tested using applicable SBs, TMs, drawings, and specifications.

10-30. Most mid-sized guided missiles are now certified as rounds and are maintained by the contractor at contractor facilities. Unit maintenance on guided missiles is limited to spot painting and replacement of items such as wings and elevons. Missile items identified by lot or serial number are inspected for serviceability. Materiel is sampled and inspected by individual lots. Missiles are inspected using the inspection table in the appropriate TM or SB.

10-31. Defects found in the sample are classified using the applicable SB, TM, or other specification. Where defects are not classified in these publications, the inspector classifies them according to SB 742-1. The results of the sample inspection are used to make serviceability decisions about the lot or group.

SURVEILLANCE RECORDS AND REPORTS

10-32. A technical history of each lot, serial number, or group of munitions is kept by surveillance personnel. This history includes results of all inspections, tests, investigations, and any unusual or changing conditions affecting the items. These records are used to evaluate the serviceability and reliability of munitions. Therefore, it is important that all information gathered be accurate and concise. The historical information needed for maintenance is usually more detailed as to the extent of the defect and the work required returning the item to service. The following information is needed to evaluate the reliability of the stockpile:

- Condition of the materiel.
- Quantity.
- Date of manufacture.

- Type of storage.
- Type of defects.
- Cause of defects.
- Results of tests.

10-33. Surveillance personnel are required to submit and maintain reports on materiel received or in storage. SB 742-1 provides guidance for preparing the following records and reports:

- DA Form 984, *Munition Surveillance Report—Descriptive Data of Ammunition Represented by Sample.*
- DA Form 2415, *Ammunition Condition Report.*
- DA Form 3022-R, *Army Depot Surveillance Record*.
- DA Form 3023, *Gage Record*.
- DA Form 3782, *Suspended Notice.*
- DA Form 4508, *Ammunition Transfer Record*.
- DD Form 250, *Materiel Inspection and Receiving Report.*
- DD Form 1575, *Suspended Tag-Materiel.*
- DD Form 1575-1, *Suspended Label-Materiel.*
- DD Form 1650, *Ammunition Data Card*.
- SF 361, *Transportation Discrepancy Report.*
- SF 364, *Report of Discrepancy.*
- Munitions inspection and lot number reports.
- Munitions suspension records, to include AMCCOM and MICOM suspension.
- Equipment logbooks and maintenance logs.
- Reports of explosions, chemical agent releases, serious accidents, and nuclear incidents.
- Small arms tracer reports.
- Storage monitoring records (local format).
- Others required by local/higher headquarters.

SAFETY

10-34. Safety in munitions maintenance is covered in AR 385-10, DA PAM 385-64, and maintenance manuals for specific munitions items. Explosives safety standards, the handling and storing of munitions, operational precautions, Q-D requirements, barricades, operational shields, personnel and explosives limits, and safety tools and equipment are discussed in Chapter 7 of this manual.

SUMMARY

10-35. This chapter has provided only general information and guidance for personnel responsible for the maintenance of munitions. Detailed maintenance and surveillance procedures for specific munitions items are in TM 9-1300 series publications. Surveillance procedures are covered in SB 742-1.

Chapter 11

Emergency Destruct Operations

When faced with the possibility of capture by the enemy, an ASA or ATP may be called upon to conduct ED operations on part or all of its stocks. This chapter discusses the reasons for emergency munitions destruction and provides guidance in aspects of planning and conducting safe operations. Also, it describes methods of destruction and elements of required training.

OPERATIONS OBJECTIVES

11-1. Emergency destruction of munitions is conducted for one of two reasons. The first is to prevent enemy use. The second is to prevent disclosure of information about classified munitions. The object of ED is to render munitions inoperable, destroy munitions and documents of value to the enemy, and render what is left too hazardous to use. By reducing the stockpile as much as possible, units ensure that the least amount of munitions is destroyed. Quantities can be reduced in several ways. One is to move as much of the munitions as possible to a safe location. Another is to issue excess amounts to using units.

AUTHORIZATION TO DESTROY

11-2. The authority to destroy munitions must be established in command operating procedures. The applicable OPLAN or SOP must specify who in the chain of command is authorized to order the ED of ASA or ATP stocks. Only divisional or higher level commanders have the authority to order destruction of munitions. The commander may delegate this authority to subordinate commanders when the situation demands. Also, the command may dictate when and how to conduct ASA or ATP ED, including the types of items authorized for destruction and the destruction methods.

11-3. The decision to destroy, the method to be used, and the items to be destroyed all depend on factors involving command policy and the logistical and tactical situation. Some of the more important things to consider include—

- Tactical situation.
- Location of the ASA or ATP.
- Amount of ammunition and the time required to destroy the ASA or ATP.
- Security classification of the munitions.
- Available materiel and trained personnel.
- Safety considerations.

These factors are discussed in the paragraphs that follow. Also, added precautions must be taken when depleted uranium munitions or armor must be destroyed (see TB 9-1300-278).

TACTICAL SITUATION

11-4. The current tactical situation provides input to the decision-making process. The various ED methods require different setup and execution times. Also, the different methods provide different possibilities for complete destruction. With more time available, more complete destruction methods can be used. If time allows, the decision to authorize ED must be made at a higher command level. However, the senior person at the ASA or ATP may be required to authorize ED to prevent enemy capture and use.

ASA OR ATP LOCATION

11-5. Where the ASA or ATP is located has a bearing on which method of destruction is used. If an ASA or ATP is near a populated area, demolition may not be practical. On the other hand, if the destroyed ASA or ATP would create an obstacle to oncoming enemy forces, demolition would be useful.

AMOUNT OF AMMUNITION/TIME REQUIRED

11-6. The amount of demolition resources and the time required to destroy an ammunition stockpile are directly related to the amount of ammunition to be destroyed and its degree of dispersion. The quickest ED method is by fire support. An ASA or ATP can be destroyed with an artillery or air attack. ED by burning or demolition requires a lot of preparation time. Burning is faster because demolition requires setting up and priming explosive charges and setting up an initiation system.

11-7. A tradeoff may need to be made. With an artillery strike, the munitions may not all be destroyed. By burning or explosive demolition, the possibility of complete destruction of the ASA or ATP is much greater.

MUNITIONS SECURITY CLASSIFICATION

11-8. Classified munitions must be evacuated if at all possible. If not possible, classified munitions will be the first to be destroyed. To ensure complete destruction, classified munitions are destroyed by the most reliable demolition method.

AVAILABLE MATERIEL AND TRAINED PERSONNEL

11-9. If the ASA or ATP has no demolition or flammable materiel, destruction methods are limited. Also, demolition materiel may be more critical for offensive purposes than for ASA or ATP ED. In this case, destruction must be carried out by burning or other available methods. Only personnel trained in ED operations and thoroughly familiar with the unit ED SOP should be permitted to conduct demolition operations.

PLANNING

11-10. Planning for ED must start immediately. It is difficult to establish SOPs because tactical and logistical situations in each combat zone vary. However, the methods of destruction are basic and flexible enough to serve as SOPs in combat emergencies. The ED plan must be either an annex to the unit SOP or a separate SOP. To ensure the plan is complete and feasible, staff it through technically qualified personnel and division, corps, or theater staff elements (i.e., EOD, the safety office, G3, and G4).

11-11. The division, corps, and theater staff agencies must thoroughly prepare for ED. Plans must address destruction priorities and procedures.

11-12. When establishing an ASA or ATP, the DAO and MMCs must plan to push ED materiel to the site. ED materiel requirements can be based on the expected daily push to the ATP (RSR for supported elements) or on the stockage objective for the ASA. To support any increased munitions flow, the MMCs or DAO must ensure that additional ED materiel is pushed to the ASA or ATP. ED materiel should be kept on hand at all times during normal operations, relocations, or evacuations. ASA and ATP personnel must be trained in ED methods and procedures. All personnel must be thoroughly familiar with the unit ED SOP and methods of destruction.

PRIORITIES

11-13. Priorities for ED are based on the tactical situation and the types of munitions stored at the ASA or ATP. ED priorities must be established in OPLANs and SOPs. Priorities may change based on the logistical and tactical situation. Munitions vital to the defense of the unit will not be destroyed. See Table 11-1 below for a suggested priority list for munitions ED.

Table 11-1. Suggested Priority List for ED of Munitions

PRIORITY	ITEM
1	Classified and special (chemical) munitions; associated manuals, records, reports, test sets, and equipment.
2	Munitions that can be used in immediate retaliation and deployed without a weapons system (e.g., grenades, land mines, small rockets [AT4]); munitions for which the enemy has weapons system capability.
3	Casualty-producing munitions (e.g., HE, antipersonnel) not included in priorities 1 and 2.
4	Noncasualty-producing and pyrotechnic munitions (e.g., signal, illuminating projectiles).

SAFETY

11-14. Observance of safety precautions is mandatory, regardless of the ED method used or the urgency of the situation. Only trained, experienced personnel may conduct ED procedures. Safety requirements determine the number of personnel engaged in ED operations. Safety considerations include the amount and type of munitions being destroyed and the size of the ASA or ATP. A minimum of two personnel must be present during all operations.

11-15. Tactical situation permitting, coordination with and warning of those units endangered by the ED operation must be accomplished to prevent casualties.

11-16. No matter which ED method is used, special care must be taken when destroying ICM, rockets, missiles, and ejection-type munitions. ICM and ejection-type munitions may expel their payload when detonated or burned. These submunitions must be treated as UXO. Rockets and missiles will be pointed away from friendly troops since they could be set off by accident during the ED process and propelled in the directions they were pointed.

11-17. When using electrical or remote firing devices during ED operations, a minimum distance of 400 meters must be maintained from radio transmitters.

BURNING

11-18. The type and quantity of munitions being burned determines the radius of the danger area around the burning site. A minimum 1,000-meter (0.6-mile) safe area must be established when surrounding units and personnel are warned and under protective cover.

DEMOLITION

11-19. The type and quantity of munitions being destroyed, the fragmentation hazard, and the protective cover provided to personnel in the area determine the radius of the danger area surrounding the destruction of munitions by demolition. The information in Table 11-2 is based on ballistic data and field experience and should be used as a guide. If there is any doubt about an item, the distance will be increased for reasons of safety. Distance may be adjusted based on the tactical situation, terrain, and available protective cover for exposed personnel.

METHODS OF DESTRUCTION

11-20. Choose methods of destruction that cause such damage that the munitions will not be restorable to a usable condition within the combat zone by repair or by cannibalization. Destruction should be planned to impede enemy troop movements without creating hazards to friendly troops.

11-21. The methods for destroying munitions listed below may be used either singly or in combination. The actual method or methods used in a given tactical situation depend on time, personnel, type of munitions, and available means of ED. These methods include firing, concealment, burning, and demolition, and are discussed below.

FIRING/FIRE SUPPORT

11-22. At the using unit, firing the munitions into enemy-held territory is the simplest and most effective way of preventing enemy capture. Another ED method is using fire support. An ASA or ATP can be effectively destroyed if it is shelled or bombed. This method is particularly useful to ensure complete destruction after burning or demolition. Also, it is quite useful as a primary means of ED when there is no time to evacuate or set up any other ED method. An advantage of ED by fire support is that it can be used even after the ATP has been occupied by enemy forces.

CONCEALMENT

11-23. Concealment is the least desirable ED method. It is viable when the lack of time precludes using other methods. If the terrain provides adequate covering, or if bodies of water are available for dumping munitions, concealment may be an excellent ED method. Puncture hermetically sealed metal cans before throwing them into water if time permits. Concealment of components such as fuzes can prevent or at least delay use by the enemy.

BURNING

11-24. Burning is less time-consuming than demolition. However, it is not recommended for all types of munitions because it rarely accomplishes total destruction. When time is a major consideration, burning may be used to destroy boxed munitions. When burning, munitions must be surrounded with combustible/flammable materiel. To guarantee an extremely brisk fire, diesel fuel, gasoline, paint thinner, or other suitable combustible or flammable liquid should be used

Table 11-2. Minimum Safe Evacuation Distance (in Meters) for Demolition Operations

Explosive Weight (pounds)	Evacuation Distance (meters)
27 and less	300
30	310
35	330
40	350
45	360
50	375
100	475
150	550
200	600
250	625
300	675
400	725
500	800

NOTES:

1—When using this table, Pounds of Explosive equals the total NEW of the munitions being destroyed plus the demolition materiel being used.

Example: 3 each Projectile 155mm HE, ADAM, D501 (NEW=1.8885x3=5.6655 NEW), 2 each demolition charge blocks, M112 (NEW=1.3x2=2.6 NEW), totaled 5.6655+2.6=8.2655 Total NEW, minimum safe evacuation distance is 300 meters.

2–-When the munitions NEW is unknown, a general rule for estimating the amount of explosives is as follows: Assume that 50 percent of the total munitions weight equals the NEW.

3–-When the NEW exceeds 500 lbs, use the formula below:

$100 \times 3\sqrt{\text{pounds of explosives}}$.

11-25. For maximum destruction, munitions-laden trailers should be pulled close together. Fuel, wood, paper, scrap boxes, propellant charges, or any combustible materiel can be used for burning. Fuel is especially useful. Fuel-soaked munitions boxes are excellent for ensuring a fire strong enough to destroy munitions.

11-26. Combustible materiel will be placed under and over the munitions to be destroyed. An initiation train of combustible materiel can be used to ignite the fire; it must be 8 meters (26 feet) in length, long enough to allow soldiers to evacuate to a safe area. If time fuse is used as the initiation train, enough fuse must be used based on the burn rate to permit evacuation to a safe area. See FM 5-250 for more information. An alternate initiation method is to shoot a full fuel can with an incendiary bullet. If it becomes necessary to use gasoline or other highly volatile, flammable liquid, extreme caution must be taken to prevent premature ignition. For greater safety, ignition should be made by electrical means or by a remote-firing device.

DEMOLITION

11-27. The way in which a demolition charge is placed can make the difference between minor damage and complete destruction. For this reason, ED demolition teams must be trained on basic demolition procedures and on all available firing systems (see FM 5-250). Demolition materiel can be saved when planning ED operations by using HE-filled munitions in conjunction with demolition charges.

11-28. ED demolition teams must understand how and where to place demolition charges on different munitions to achieve complete destruction or to make the item unusable by the enemy. Demolition teams must be familiar with the preferred procedures for destruction of munitions in applicable TM 43-0002-series manuals.

11-29. Placements of demolition charges vary for different types of munitions. Also, placement of the charge may be different for items while in shipping and storage configurations versus when they are removed from the containers.

TRAINING

11-30. Rehearsal of responsible personnel in all phases of destruction is mandatory with special emphasis on training in demolition techniques. The training program should also include instruction in selecting sites, blocking communication routes, and impeding enemy movement.

11-31. Demolition explosives afford an effective means of destroying munitions to prevent enemy use. Demolition personnel must be familiar with pertinent provisions of DA Pam 385-64, FM 5-250, TMs 9-1375-200/2 and 9-1375-213-12, and TM 43-0002-series manuals.

11-32. Local EOD units can be contacted to provide technical assistance during hands-on training sessions and to assist in developing ED SOPs. The munitions unit commander must provide training munitions for all hands-on sessions. The STRAC manual provides the munitions allocations for demolitions training.

SUMMARY

11-33. The authority for ED, whether direct or delegated, must be identified in the appropriate OPLAN and SOP. The decision to destroy munitions is based on safety, logistical, and tactical considerations that may have implications beyond what appears to be an imminent enemy threat. ED operations should be considered as an option of last resort and should always receive planning and safety emphasis.

Chapter 12

Captured Enemy Ammunition

This chapter discusses organizations that have an interest in CEA reporting procedures and unit responsibilities. The management of CEA is an integral part of the TECHINT mission. It supports the tactical commander's effort to fight and win the battle. Evaluation of CEA provides valuable data to the commander that helps in countering the enemy's technological advantage. Exploitation of CEA and TECHINT reporting is a major part of the all-source intelligence effort. It involves everyone from the individual soldier to policy makers and all levels of command. Often, the TECHINT process begins when one soldier finds something new on the battlefield and takes steps to report it. The information or CEA is evaluated and frequently exploited at progressively higher levels until a countermeasure is produced to neutralize the enemy advantage.

HISTORICAL PERSPECTIVE

12-1. In the 1920s, Germany developed weapons and weapon systems that would be used against the allies in the 1940s. The allied nations did not include TECHINT in intelligence collection efforts. As a result, German scientific and technical advances went largely unnoticed. By the time information did come to light and was made available to Washington and London, it was ignored. These weapons were used during World War II with devastating results.

WORLD WAR II

12-2. During the air battle for Europe, the British used TECHINT to counter the German antiaircraft and night fighter defenses. They did this by exploiting captured aircraft radios and a captured radar station. This collection led to the publishing of new technical material, to include the following:

- Technical manuals and handbooks on enemy weapons.
- Training aids.
- Updates to handbooks on the German and Italian armies.

The US started a successful TECHINT program in the fall of 1943, but abandoned the program immediately after the war.

KOREAN WAR

12-3. At the beginning of the Korean War, the US finally discovered it had little hard data on enemy weapon systems. The DOD realized that TECHINT had to be ongoing if effective countermeasures were to be developed. Once again, TECHINT was established.

VIETNAM WAR

12-4. During the Vietnam War, the Captured Materiel Exploitation Center was established. Its mission was to manage and coordinate analysis of CEE and technical documents. The CMEC dispatched teams of experts and analysts into the tactical zone of each corps to evaluate and exploit captured items.

GULF WAR

12-5. During the Gulf War, coalition forces and the US Army captured a tremendous amount of enemy munitions. The US was faced with the dilemma of how to handle and dispose of these munitions. While CEA doctrine and procedures were briefly mentioned in several documents, thorough, concise procedures were not available.

TECHINT MISSION

12-6. The TECHINT mission is the end product of a complex process that involves collecting, analyzing, and processing information on foreign technology and CEM. It is also the result of studying the performance of foreign materiel, including munitions and their operational capabilities. Foreign materiel encompasses the following:

- Weapon systems.
- Equipment.
- Apparatus.
- Documents.
- Technology.
- Munitions.
- Supplies of a foreign military force or nonmilitary organization.

12-7. Like other intelligence disciplines, TECHINT guards against surprise in war or SASO. It provides several distinct types of input to the all-source intelligence product, as follows:

- Assessment of capabilities and vulnerabilities of enemy weapon systems.
- Warnings of changes in enemy tactics due to new or changing technology.
- Countermeasures.

12-8. The TECHINT system has two parts within DOD. The first is the S&TI community, which concentrates on decision-making and the TECHINT requirements of strategic policy. The second is made up of the US Army's battlefield TECHINT elements. These elements support commanders in preparing for and waging war or conducting SASO. The two parts are described below.

TECHINT ORGANIZATIONS

12-9. The scientific and intelligence activities discussed in this section are primarily concerned with peacetime exploitation of foreign materiel, including CEA.

US Army Intelligence Agency

12-10. The USAIA is a field-operating agency of the DCS that produces and disseminates intelligence information on foreign ground forces and their weapon systems. Also, it provides threat analysis and related projections to the Army's combat development community.

National Ground Intelligence Center:

12-11. NGIC produces and maintains intelligence on foreign scientific developments, ground force weapons systems, and associated technologies.

US Army Materiel Command

12-12. The USAMC shares responsibility for managing the overt acquisition of foreign materiel for TECHINT purposes. The USAMC buys foreign materiel for exploitation purposes in the US, as well as through its centers in Europe and the Far East.

US Army Intelligence and Security Command

12-13. The INSCOM has the major responsibility for SASO TECHINT operations. It fulfills this responsibility through its TECHINT oversight function and by exercising operational control over the FMIG during SASO.

Foreign Materiel Intelligence Group

12-14. At EAC, the FMIG is a battalion-sized organization located at Aberdeen Proving Ground, MD. This group is the Army's only active duty TECHINT unit. Responsibilities of the FMIG include the following:

- Conducting TECHINT operations.
- Preparing TECHINT reports in support of Army, joint, and combined operations.
- Acting as the HQDA executive agent for foreign materiel used for training purposes.

US Army Armament Research Development and Engineering Center

12-15. The primary responsibility of ARDEC during SASO is to perform detailed evaluations of foreign munitions. ARDEC is located at Picatinny Arsenal, NJ.

BATTLEFIELD ACTIVITIES

12-16. TECHINT activities on the battlefield are usually initiated at the unit level with subsequent involvement of other specialized support teams, command level staffs, and higher echelon organizations with direct responsibility for planning, operations, and logistics.

Response Units

12-17. Response units start the TECHINT process. They are responsible for initial identification, reporting, and safe handling of CEA. Types of response units are discussed briefly below.

12-18. ***Capturing unit.*** The capturing unit is the first unit that discovers or captures enemy munitions. Recovery and evacuation of CEA is a command responsibility at all echelons. After reporting the CEA, the capturing unit's biggest responsibility is to provide security of the CEA until the unit receives disposition instructions. The immediate headquarters of the capturing unit is responsible for the following:

- Obtaining and providing prompt disposition instructions.
- Assisting the capturing unit with safeguarding, recovering, and evacuating the CEA.

The capturing unit may be required to help destroy or coordinate the movement of CEA. Once the CEA is turned over to another unit or collection point, the capturing unit is relieved of further responsibilities.

12-19. ***Explosive ordnance disposal.*** EOD units identify and request disposition of first-seen ordnance and CEA of intelligence value and, if required, attempt render-safe procedures. The EOD unit submits required reports through TECHINT channels, if requested.

12-20. ***US Army Technical Escort Unit.*** The TEU has a worldwide mission to secure, transport, and dispose of nuclear, chemical, or biological CEA after EOD personnel have classified it as safe to handle. The TEU has EOD resources.

12-21. ***TECHINT teams***. TECHINT teams initially identify and exploit CEA. They assist corps and divisional tactical operations centers. TECHINT teams rarely perform detailed analysis because there are so few teams and few laboratory facilities. These teams normally consist of a team leader and ten specialists, one from each of the following specialties:

- Tracked vehicles.
- Wheeled vehicles.
- Weapon systems.
- NBC equipment.
- Fire control systems.
- Aviation fire control systems.
- Intercept and jamming equipment.
- Communications equipment.
- Medical equipment.
- Antitank guided missiles.
- Munitions.

Staffs

12-22. Staffs at all levels use TECHINT information to update and develop plans to support the commander's intent. Based on this information, staffs advise the commander of capabilities and technological advances of opposing forces during war and SASO.

12-23. ***Intelligence staff.*** The J2, G2, or S2 serves as the commander's principal staff office for all MI matters. This staff has primary responsibility for the commander's battlefield TECHINT effort.

12-24. ***Operations staff.*** The J3, G3, or S3 serves as the commander's principal advisor for operations, plans, organization, and training. This staff incorporates TECHINT into all parts of unit plans and operations.

12-25. ***Logistics staff.*** The J4, G4, or S4 serves as the commander's principal staff office for supply, maintenance, transportation, and services. As the logistics planner, this staff coordinates accountability, movement, and resupply and is essential to the TECHINT system.

Intelligence Units/Activities

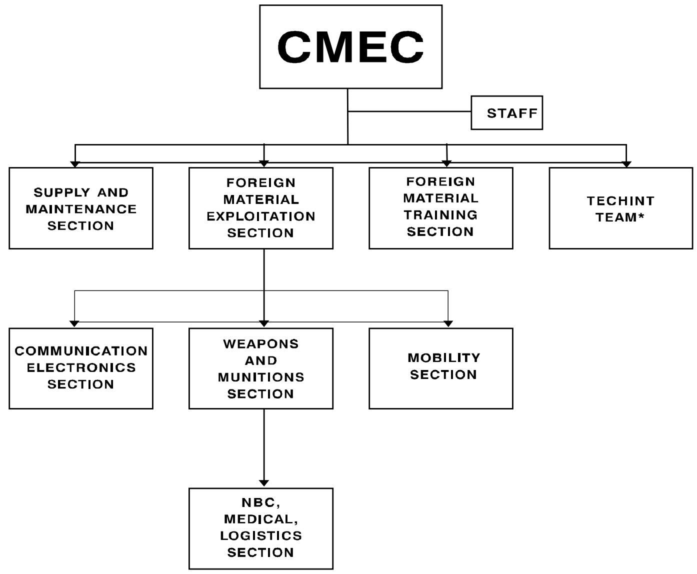
12-26. Intelligence units and activities receive, evaluate, process and disseminate information from response units and staffs. They ensure the TECHINT information is channeled to the appropriate intelligence agency.

12-27. ***Military intelligence units.*** During routine operations, MI units may accidentally discover incidental items of battlefield TECHINT. All MI units are responsible for establishing procedures for handling, screening, and reporting TECHINT-related items. Also, these units coordinate with operations and logistics staffs on intelligence matters. MI unit missions include the following:

- Interrogation.
- Document exploitation.
- Imagery interpretation.
- Electronic warfare.
- Unmanned aerial vehicle operations.

12-28. ***Captured materiel exploitation center.*** The CMEC is formed from the assets of organic and attached TECHINT elements augmented by other SMEs. (See Figure 12-1, page 12-6.) It manages the command battlefield TECHINT system through the MI brigade and the G2. When possible, other armed services should combine assets for the acquisition and exploitation of CEM, to include CEA. When this occurs, the CMEC becomes the JCMEC.

12-29. ***Joint captured materiel exploitation center.*** The JCMEC consists of TECHINT personnel from each participating service. As in the CMEC, the JCMEC commander is the TECHINT advisor to the J2.



*One or more TECHINT teams are deployed for each corps-equivalent command assigned within the theater command. The teams are staffed by one each TECHINT specialty found within the CMEC or task-organized to fit specific local situations. Based on need and assets available, other teams can be organized and deployed.

Figure 12-1. CMEC Organization

Other Units/Activities

12-30. Many other units may be involved in TECHINT operations involving CEA. The depth of involvement depends on the specific CEA found. These units may include the following:

- Combat arms.
- Special operations.
- Military police.
- Chemical.
- Medical.
- Engineer.
- Civil affairs.
- CSS units.

UNIT RESPONSIBILITIES

12-31. Each unit involved with CEA has specific responsibilities related to recovery, evacuation, safety, transportation, storage, and management. These units and their responsibilities are discussed below.

TRANSPORTATION UNITS

12-32. The transportation of CEA is typically part of logistical support requirements. Because it is critical that CEA be transported safely, it is being given special emphasis here.

12-33. The theater commander through the CMEC directs final disposition of CEA. Before moving CEA, an EOD or TEU team must certify that it is safe to handle and transport. An ammunition inspector should be consulted about safe loading, tie-down, and transportation procedures. The capturing unit should coordinate this support early in the planning process. Both the CMCC and CMMC must be involved in planning any movement of CEA.

12-34. The shipping activity must properly load and tie down all munitions, including CEA. The shipper must provide guidance to drivers on all aspects of safety and instruct them on proper firefighting procedures.

12-35. Accountability procedures for CEA are identical to procedures used for US munitions. Motor vehicle drivers sign for the shipment on a DD Form 1384 and are responsible only for the total number of pallets or boxes on their vehicles. Drivers do not sign the shipping documents, which are in the shipping envelope attached to the munitions pallets or boxes.

COLLECTION POINTS

12-36. The collection point commander or NCOIC is responsible for the receipt, storage, issue, shipment, and accountability of the CEA. Once the CEA is received at an ASA, an ammunition inspector inspects the CEA and determines its serviceability.

12-37. CEA is always stored separately from US stocks. It is stored and accounted for in the same manner as like US munitions. All Army activities holding CEA are required to account for the materiel IAW the basic accounting principles of ARs 710-2 and 735-5 and DA Pams 710-2-1 and 710-2-2. Serviceable CEA must be separated from unserviceable CEA within the CEA storage location. Based on the commander's assessment of the threat and risks involved, CEA will be stored at the ASA under one of the following systems:

- ***Peacetime.*** Storage by NEW and SCG.
- ***SASO and Wartime.*** Storage by gross tons and SCG (when approved by MACOM commander.

12-38. The site commander or NCOIC reports and requests disposition instructions through logistic channels as directed by the servicing MMC. If the CEA is retrograded, the procedure is the same as for like US munitions.

OTHER SUPPORT UNITS

12-39. Ordnance, aviation, medical, transportation, and quartermaster units may be called upon to perform the following tasks:

- Recover and retrograde CEA.
- Establish collection points.
- Operate collection points.

- Maintain storage location records.
- Submit reports on CEA in logistic channels.

CAPTURE AND REPORTING PROCEDURES

12-40. When a soldier or unit finds munitions, the finding must be reported immediately through command channels to the battalion S2. The report will follow the SALUTE report format (see Figure 12-2). FM 21-16, *Unexploded Ordnance (UXO) Procedures*, may be used to make a tentative identification of the munitions (i.e., projectile, grenade, or bomb). The report may be submitted orally or in writing by any means available. The soldier or unit then safeguards the found munitions or continues the mission as directed.

DANGER

All munitions found on the battlefield must be considered booby-trapped and extremely hazardous. Report all munitions as UXO regardless of country of origin.

12-41. Intermediate echelons of command forward the SALUTE report to the supporting battlefield TECHINT element. The TECHINT element sends disposition instructions back to the capturing unit. Usually, the instructions direct the unit to continue safeguarding the CEA until an EOD team or a TECHINT element arrives. Once on site, the EOD team, TECHINT element, or higher element determines if the items found have intelligence value. The higher headquarters may direct the capturing unit to initiate evacuation or simply abandon the CEA. When abandoning CEA, the responsible unit must mark the site. CEE tags, placed on stakes near the item, will be used to describe the CEA (see Figure 12-3, page 12-10). There are no special tags for CEA. *Do not attach tags directly to hazardous munitions.*

12-42. Proper marking of the site makes it easy to find the CEA once the capturing unit leaves. Also, it alerts others crossing the area that CEA has been found and reported. Marking includes any of the following methods:

- Use engineer tape or other materials and post signs to mark the area.
- Build a small berm around the stack or CEA area.
- Surround the area with CEE-tagged stakes.

TECHINT REPORTING PROCEDURES

12-43. EOD, TEU, and TECHINT teams are qualified to identify captured munitions. An EOD response team may be dispatched to a site to investigate and render safe the munitions. If an EOD team cannot be sent immediately, the CEA will be marked and left for later evaluation. TEUs have EOD resources available and may be able to render safe the CEA.

12-44. TECHINT teams are sent to CEA sites to complete technical intelligence reporting. If a TECHINT team is not available, an EOD team may be asked to identify and evaluate the CEA and activate the TECHINT reporting process. EOD may be directed to segregate and/or dispose of the CEA if it is hazardous or armed. If the CEA has chemical fillers, a TEU may be requested to evaluate, process, and evacuate the CEA.

EXAMPLE

SALUTE REPORT

TO: G2, V CORPS DTG: 230900Z AUG 98

FROM: 1-96 FA, 23 AD REPORT NO: 07-035

1. SIZE: N/A
2. ACTIVITY: Captured Ammunition
3. LOCATION: West bank of Fulda River, south of Bebra, six-digit grid NB 553476
4. UNIT: 1-96 FA, 23 AD (capturing unit)
5. TIME: Ammunition captured at 230230Z Aug 98
6. EQUIPMENT: N/A
7. REMARKS/OTHER INFORMATION: Response to priority intelligence requirement (IPR) 23-0016-93. Ammo site secured, awaiting disposition instructions.

Figure 12-2. Sample Format for SALUTE Spot Report

12-45. If the item is identified as a first-seen CEA, the TECHINT team, EOD team, or TEU forwards a PRETECHREP through command channels to the CMEC (see Figure 12-4, page 12-11). The PRETECHREP gives a general description of the CEA and alerts tactical units to technical information of immediate tactical importance.

12-46. Based on the PRETECHREP, EOD teams may be asked to prepare the Type B COMTECHREP (see Figure 12-5, pages 12-11 and 12-12), which is specifically for EOD. It includes the CEA itself or summaries, diagrams, photos, and samples. Type A COMTECHREP is for USAF TECHINT items. The Type C COMTECHREP is for items not reported on the Type A or B report. If the CMEC directs destruction of the CEA, the EOD team completes the disposal. Once the CEA is destroyed or moved to a collection point, the capturing unit is no longer responsible for the munitions. For more information, see FM 34-54.

PROCEDURES FOR MOVING CEA

12-47. CEA can be evacuated to the nearest collection point once the TECHINT element determines it has no intelligence value. Corps or division establishes CEA collection sites, usually at primary Class V ASAs. These collection points may be at any one of the ASAs or ATPs.

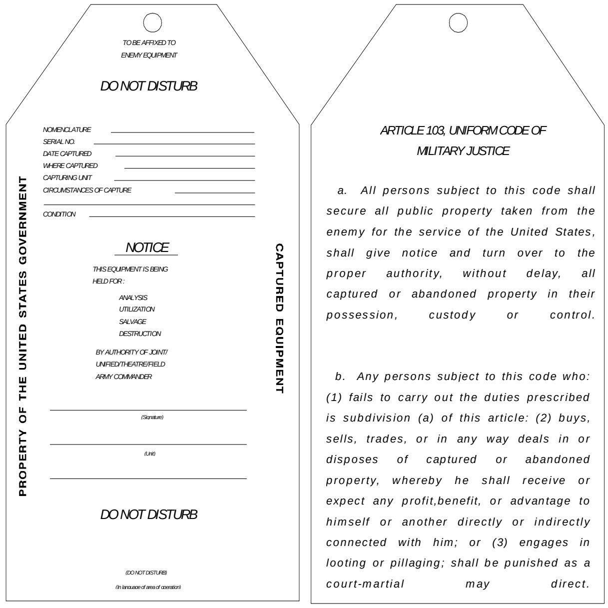


Figure 12-3. Sample CEE Tag

WARNING
All CEA must be certified safe by EOD and/or QASAS prior to any movement.

12-48. Capturing unit transportation assets may be used to evacuate CEA to the nearest collection point. The mission of the capturing unit must be considered when deciding whether the unit will evacuate the CEA. Transportation units may transport CEA from the site of discovery to the collection point or to the rear.

12-49. The capturing unit's higher headquarters, along with the DISCOM and COSCOM, coordinates required transportation. The local MCT notifies the collection point commander of an inbound shipment. EOD, QASAS, or other munitions personnel provides guidance on safe handling and evacuation of CEA. Trained munitions personnel supervise handling and shipment of CEA. CEA is transported in the same manner as similar types of US munitions.

12-50. In certain situations, if a threat exists, the CEA may be evacuated before evaluations or reports are completed. The theater commander determines disposition of CEA through the TECHINT element and the CMEC. See Figure 12-6, page 12-13, for a diagram of CEA movement in a mature theater.

12-51. In an immature theater, movement to a collection point may be left out to return CEA to the rear. The intelligence element or EOD team notifies the local commander of the CEA. The movement is coordinated within the division or corps by the DISCOM or COSCOM. A TEU team should escort chemical or biological material to the nearest collection point or rear.

EXAMPLE

(Classification)

PRETECHREP

A. Type of equipment and quantity.

B. Date and time of capture.

C. Location (map reference).

D. Capturing unit and circumstances of capture.

E. Enemy formation from which captured and origin.

F. Brief description with serial numbers and, if possible, manufacturer.

G. Technical characteristics with an immediate value, including information or any photographs available.

H. Time and origin of message.

I. Present location of CEE.

(Classification)

Figure 12-4. PRETECHREP Format

EXAMPLE

Confidential when filled in)

COMTECHREP–TYPE B (EOD Report)

Section I. (U) DESCRIPTIVE INFORMATION

1. (U) IDENTIFICATION. See Figure for physical appearance and dimensions. NOTE: This will be an external view (when possible) and not show internal components.

a. (U) Designation. Ordnance designation (if known) with transliteration of foreign alphabet. Example: M45

b. (U) Type. Used to summarize the key functional aspects of the items. Example: This is a High Explosive Rocket Assist (HERA) projectile.

c. (U) Painting and Markings. Record all paintings, surface treatments, and markings.

d. (U) Features. Point out unique or distinguishing external features of the item that are not obvious in the drawings.

2. (U) DESCRIPTION.

a. (U) Material. Include information pertaining to the major external components; for example, "plastic," "aluminum."

b. (U) Weight. Give the approximate weight if known.

Figure 12-5. Type B COMTECHREP Format

EXAMPLE (Continued)

3. (U) HAZARDOUS COMPONENTS.

ITEM	QTY	LOCATION	EXPLOSIVE	HE WEIGHT

List Hazardous components (if known).

4. (U) FUNCTIONING. Explain the operation of the ordnance, particularly the components of the ordnance involved with initiating the explosive train.

5. (U) APPEARANCE. It must be known for certain that the item is unarmed if the item is to be treated as such.

a. (U) Unarmed Condition. Example: The item is unarmed if not fired.

b. (U) Armed Condition. Example: Consider the item armed if it has been fired.

Section II. (C) EOD PROCEDURES. (EOD USE ONLY)

6. (U) RENDER SAFE PROCEDURE FOR THE UNARMED CONDITION.

a. (C) PROPOSED: (Develop and record prior to completing RSP).

b. (U) Proceed to disposal.

7. (U) RENDER SAFE PROCEDURE FOR THE ARMED CONDITION WARNINGS.

a. (C) PROPOSED: (Develop and record prior to completing RSP).

b. (U) Proceed to Disposal.
Continued:

8. (U) DISPOSAL PROCEDURE.

a. (U) Unarmed. Transport hazardous components to safe disposal area and dispose of by detonation.

b. (C) Armed.

(1) (Include quantity of explosives used to dispose of item).

(2) Detonate remotely.

(Confidential when filled in)

Figure 12-5. Type B COMTECHREP Format (Continued)

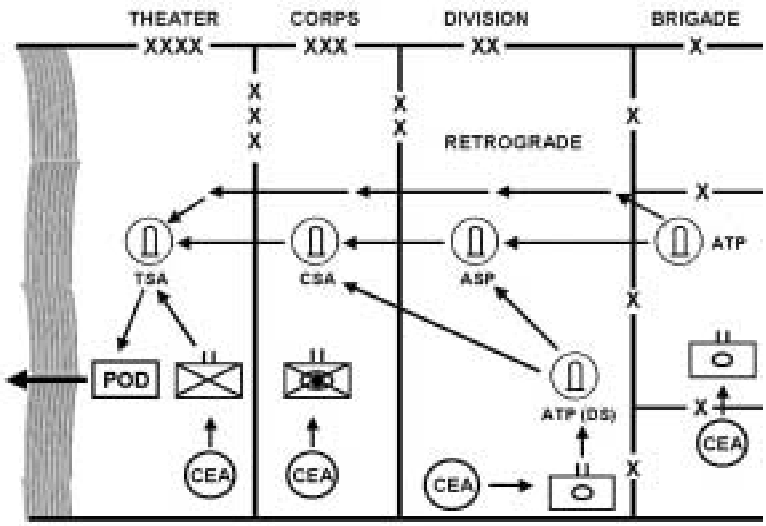


Figure 12-6. CEA Movement in a Mature Theater

CMEC PROCESSING OF CEA

12-52. The CMEC is the first real processor of CEA. When it receives CEA, the CMEC determines its level of TECHINT value. If the item is on the TECHINT requirement list, or it is of TECHINT interest, the CMEC concentrates on exploiting the CEA for immediate tactical or operational use.

12-53. CMEC specialists conduct rapid, initial scientific and technological analyses of CEA in their battlefield laboratory. Any immediate countermeasure, information, or intelligence they develop is quickly distributed to appropriate combat, CS, and CSS units. At the same time, the CMEC quickly evacuates the CEA to CONUS for an in-depth exploitation of the item.

12-54. The CMEC coordinates evacuation of CEA of special TECHINT interest to and from the CMEC. For items that cannot be evacuated, CMEC organizes and deploys a quick reaction team to coordinate the evacuation of the item or to exploit it on site.

MANAGEMENT AND DISPOSAL OF CEA

12-55. CEA must be inventoried and accounted for just like US munitions. If CEA arrives at a collection point unidentified but clearly recognized as a projectile, propelling charge, fuze, and so forth, then a pseudo catalog data record may be designated and entered into SAAS to account for the item. The supporting MMC assigns and standardizes pseudo catalog data records within the theater.

ISSUING CEA

12-56. In unique circumstances, CEA may be issued to using units in the same manner as US munitions. All requests for serviceable CEA are approved and assigned a priority for issue to US units engaged in special missions or training by higher headquarters. CEA is issued based on the following priorities:

- Intelligence.
- Special warfare.
- Special operations forces.
- Combat units.
- CS and CSS units.
- Substitutes or supplements to US munitions.

DISPOSAL OF SERVICEABLE CEA

12-57. Serviceable CEA is evacuated, collected, and stored wherever directed by higher headquarters. The CMEC, in coordination with the TAMMC or CMMC, usually makes this decision. Emergency or immediate destruction of serviceable CEA takes place under the following conditions:

- If recapture is imminent due to location of the CEA.
- If EOD or TECHINT declares the CEA hazardous to the safety of troops.

If the CEA is to be destroyed, all factory markings should be carefully recorded (and photographs taken, if possible) before destruction.

DISPOSAL OF UNSERVICEABLE CEA

12-58. ASAs routinely destroy unserviceable CEA. However, the following points must be considered before destruction takes place:

- ASAs must first support all demolition requirements of US units with on-hand demolition materials.
- If disposal of US munitions using serviceable demolition material has been authorized by higher headquarters, CEA should be included in that operation.
- Unserviceable CEA will be included only if added demolition materials are not required. Higher headquarters approval is not needed for the addition of unserviceable CEA when sufficient demolition materials are on hand.
- The ASA commander must select an appropriate disposal method for CEA that does not use serviceable demolition materials.

SUMMARY

12-59. Certain types of CEA have high potential for intelligence value. Capturing and support units should understand the importance of adhering to handling, reporting, and transportation requirements. Safety is implicit in the responsibilities of any type unit involved with CEA. Munitions units in particular must exercise caution and follow good management practices in storing, moving, and disposing of CEA. Loss of personnel due to detonation of munitions caused by improper handling, processing, and transportation reduces the significance of any intelligence value.

Appendix A

Ammunition Basic Load

Ammunition basic loads are MACOM designated quantities of Class V supplies that allow units to initiate combat operations. Basic loads are combat-deployable using organic transportation in a single lift. This appendix provides a list of references and general guidelines relevant to all Army units for determining personnel/command responsibilities, implementing requisition and storage procedures, and conducting inventory and quality assurance programs.

RESPONSIBILITIES

A-1. Responsibilities of key personnel/commands for ABL management are as follows:

- *Commanders* at all levels coordinate distribution of ABL data, review ABL computations, approve ABL authorizations, ensure ABL is on hand or on requisition, maintain the unit's ABL file, conduct annual internal reviews of the ABL file, and coordinate with supporting ammunition inspectors to ensure stockpile serviceability.
- *Ammunition Supply Points or Depots* manage stockpiles and coordinate with the supporting MMC to ensure enough ammunition is on hand and serviceable to provide for all supported units. Also, they maintain a suspense file of all prepositioned requests and coordinate requirement updates with supporting units at least annually.
- *QASAS* perform inspections of ABL in the possession of the owning unit at least annually. QASAS also notify owning units of any ammunition information notices that may affect their on-hand ABL.
- *Supporting MMCs* coordinate with supported units and the ASPs/depots to ensure adequate serviceable munitions stocks are on hand. This is accomplished by ensuring that ABL shortages are placed on requisition and providing disposition instructions for ammunition excess to ABL requirements. The installation commander/ammunition office may be required to accomplish the MMC related management.
- *The NGB Chief* prepares ABL data for ARNG units designated to mobilize. Also, he forwards the data to ARNG state headquarters for distribution to units.
- *ARNG state headquarters* distribute automated and manually prepared ABL data to ARNG units for review and update. The headquarters reviews and approves ARNG changes to ABL authorization lists, forwards approved lists and requests for issue to mobilization stations, conducts annual reviews of unit ABL files, and provides status to the chief of the NGB.

BASIC LOAD AMMUNITION

A-2. Basic load ammunition encompasses conventional ammunition and missiles that a unit must have on hand or on request at all times. Basic load can be further broken down and defined as:

- *TAT ABL*. Ammunition that either can be carried by or accompanies the soldier, uploaded on a combat vehicle or on organic transportation, during deployment.
- *Non-TAT ABL*. Ammunition that cannot accompany the soldier or be loaded in or on unit combat or transport vehicles during deployment.
- *Ammunition combat loads*. HQDA designated quantities carried by each deployable weapon system to initiate combat as determined by TRADOC materiel developers.

PROCEDURES AND ACCOUNTABILITY

A-3. AR 710-2 and MACOM policies authorize basic load ammunition. Drawn basic load ammunition is maintained on property books IAW hand receipt procedures described in DA Pam 710-2; records of responsibility are required. MACOMs designate which units are required and able to stock ABL and which will have on hand a properly authenticated request for issue. Guidelines for determining ammunition responsibility and accountability are as follows:

- When a unit is approved to physically draw and store their ABL, they will prepare a properly authenticated DA Form 581 and submit it to the supporting ASP/depot. MACOMs establish procedures for submitting and obtaining required approval on the DA Form 581.
- All other units not designated to draw and store their ABL will submit a properly authenticated DA Form 581 to the supporting ASP/depot for planning purposes. Both the ASP/depot and the unit will maintain a copy of the request. The request is used to ensure that adequate serviceable stocks are on hand and to speed the issue process in event of deployment. MACOMs establish specific procedures for the units to follow.

A-4. Various methods apply to ABL accountability. How ABL is stored determines which of the following methods will be used:

- The storage location retains accountability for the ammunition when the basic load is not issued to the unit and is stored at the supporting ASP or depot. The ASP/depot assigns the ammunition to the MACOM designated account code and accounts for it using the approved ammunition STAMIS (usually SAAS-ASP). The unit should record on the property book page the document number from the DA Form 581 request. ABL managed in this manner need not be segregated from other on-hand stocks at the ASP/depot.
- The unit maintains accountability when the ASP/depot issues the basic load to the unit, posts it as a loss to the ammunition STAMIS, and the unit provides its own secure storage area. Responsibility is assigned to the individual having custody of the keys to the storage area using hand receipt procedures described in DA Pam 710-2-1.

- The unit maintains accountability when the ASP/depot issues the basic load to the unit, posts it as a loss to the ammunition STAMIS, but provides a locked storage location for access because the unit lacks secure storage facilities. Responsibility is assigned to the individual having custody of the keys to the area using hand receipt procedures described in DA Pam 710-2-1.
- The unit maintains accountability when the ASP/depot issues the basic load to the unit, posts the issue as a loss to the ammunition STAMIS, and provides secure storage for the ammunition but does not limit access to the owning unit. Responsibility for the ammunition is assigned to the ASP/depot accountable officer using hand receipt procedures in DA Pam 710-2-1.

INVENTORY

A-5. Basic load ammunition will be inventoried IAW AR 710-2. MACOMs will establish procedures and guidance for maintaining physical security and conducting basic load inventories IAW DA Pam 710-2-1. At a minimum the inventories must–

- Be accomplished monthly when ABL is issued to the owning unit and is stored in a secure location (IAW AR 190-11).
- Be accomplished daily when ABL is in the possession of the owning unit and not stored in a secure location (IAW AR 190-11).
- Be accomplished semiannually (CIIC 1, 5, and 6) and annually (other than CIIC 1, 5, and 6) when stored and accounted for by the ASP/depot.

QUALITY ASSURANCE

A-6. Only Condition Code A ammunition (serviceable, issuable without qualification) will be used to fill basic load requirements. Units will coordinate with the supporting QASAS to have any on-hand basic load inspected at least annually by an ammunition inspector. Units having on-hand ammunition stocks must also coordinate with the supporting QASAS or ASP/depot to ensure that they obtain relevant ammunition information notices of suspensions or restrictions. If on-hand ammunition is determined to be unsuitable for continued use as basic load, the unit will coordinate with the supporting ASP/depot for turn-in and replenishment.

REFERENCES

A-7. The following references apply to this appendix:

- AR 190-11, *Physical Security of Arms, Ammunition, and Explosives.*
- AR 220-10, *Preparation for Overseas Movement of Units*.
- AR 710-2, *Supply Policy Below Wholesale Level.*
- DA Pam 710-2-1, *Using Unit Supply System*.
- DA Pam 710-2-2, *Supply Support Activity Supply System*.
- SB 38-26, *Ammunition Supply Rates (Classified).*

Appendix B

Guidance for Commanders

This appendix contains information for review by munitions company commanders and modular platoon leaders to assist in analysis and evaluation of unit operational readiness for combat or SASO. Checklists should be developed to generate SOP-level of detail. Also, theater and corps level OPORDs and OPLANs should be consulted.

DOCTRINAL CONSIDERATIONS

B-1. Army doctrine requires that munitions units be capable of successfully executing their mission without lengthy adjustments or train-up periods. An effective training program that emphasizes collective and individual training and builds leadership skills is critical to successful execution. Training management is the primary responsibility of the unit commander. METL development and training must focus on the unit's wartime mission.

LOGISTICS CHARACTERISTICS

B-2. Review the five logistics characteristics necessary for munitions support for combined arms operations:

- *Anticipation* of future events and needs of combat commanders.
- *Integration* of logistical support into tactical and operational plans of combat commanders.
- *Continuity* of munitions support for depth, momentum, and initiative.
- *Responsiveness* to changing needs of combat commanders.
- *Improvisation* to allow reaction to unexpected and unanticipated events.

TACTICAL SUSTAINMENT

B-3. Review the four support considerations to be used for tactical CSS sustainment:

- Support combat commander's intent.
- Support as far forward as possible.
- Maintain TAV to support combat forces.
- Rely upon the Army's system of effective leadership to adapt to needs of the battlefield.

B-4. Review the factors to be considered for tactical sustainment:

- Determine combat commander's priorities for support.
- Identify consumption factors for the type of operation being planned.
- Determine status of stockage levels and critical shortages.
- Determine threat to supply operations in the rear and forward.
- Determine tactical contingencies that may have to be supported.

- Identify locations of supporting and supported units.
- Identify locations of MSRs.
- Identify locations of higher headquarters and supporting MMC.
- Review plans for transportation and aviation resupply support.
- Review applicable Class V plans and annexes.
- Determine requirements for retrograde support.

OPERATIONAL SUSTAINMENT

B-5. Review the factors to be considered for maintaining supply operations:

- Establish effective physical security SOPs and plans.
- Determine method of munitions supply.
- Evaluate operational effectiveness of SAAS-MOD.
- Evaluate site location and layout.
- Establish liaison and communication with supporting and supported units, higher headquarters, MMCs, and transportation units.
- Plan for support of tactical movement of unit personnel, equipment, and stocks.
- Identify plans for technical assistance support of combat units.
- Determine requirements for added collective and individual training.

RECEIPT, ISSUE, AND STORAGE

B-6. Review the factors to be considered with receipt, issue, and storage operations:

- Determine availability and adequacy of MHE and personnel (military and civilian) to conduct effective supply point operations.
- Determine compliance with Q-D, explosive safety standards, and licensing requirements.
- Ensure that munitions are being stored safely IAW with DA Pam 385-64.
- Establish SOPs for receipt, issue, and storage operations.
- Establish SOPs for firefighting, physical security, routine and emergency destruction, and NBC and UXO procedures.
- Evaluate munitions management and stock control procedures.
- Ensure that inventory and accountability procedures are maintained with 100 percent accuracy.
- Ensure that munitions reporting requirements are met.
- Determine requirements for added collective and individual training.

MAINTENANCE OPERATIONS

B-7. Review the factors to be considered for maintenance operations:

- Evaluate unit maintenance resources, procedures and priorities.
- Forecast the impact of personnel and equipment shortfalls on unit capabilities.

- Identify plans for maintenance support.
- Identify and establish liaison with supporting maintenance units/activities.
- Identify plans for evacuation of battle-damaged equipment.
- Establish maintenance operations SOP and evaluate availability of supplies and equipment.
- Determine requirements for added collective and individual training.

REDEPLOYMENT OPERATIONS

B-8. Review factors to be considered for redeployment:

- Develop redeployment plans and procedures.
- Determine accurate status of personnel and equipment.
- Ensure that retrograde of stocks is conducted safely, and that all safety standards are enforced.
- Determine requirements for EOD support if applicable.
- Identify plans for transportation, maintenance, personnel, medical, financial, religious, POL, PLL, supply, and other life support.
- Ensure that physical security plans and procedures are followed.
- Coordinate redeployment plans with supporting and supported units to ensure understanding.
- Coordinate changes in redeployment plans with key NCOs to prevent false rumors from damaging unit morale.
- Ensure a safe, secure, and efficient redeployment.

Appendix C

Forecasting and Managing Training Ammunition

Units are authorized by AR 5-13 to use conventional ammunition during readiness training for combat. The Army training goal is a combat ready force prepared to mobilize and deploy on short notice and to fight and defeat the enemy. This appendix provides general guidance on forecasting and managing training ammunition. Specific references to appropriate DA pamphlets are included for calculating and forecasting ammunition requirements.

TRAINING STANDARDS AND STRATEGIES

C-1. The Standards in Training Commission was established in 1982. Its mission is to determine quantities and types of munitions required for soldiers, crews, and units to attain and sustain weapons proficiency relative to readiness levels. Weapons committees (i.e., Air Defense, Armor, Aviation, Engineer, Field Artillery and Infantry) develop weapons training standards and strategies, and the STRAC Steering Committee reviews and approves them. DA Pam 350-38 identifies weapons and weapon systems for which training programs have been written and approved. Commanders must examine each strategy as it applies to the unit's MTOE, METL, training level, time available, and unique training needs. Also, commanders must consider the unit's overall training program and objectives as specified by the applicable SM, CTT, and ARTEP, as well as the availability of simulators and devices.

C-2. Training strategies and ammunition requirements are not prescriptive. Commanders must determine and design strategies that allow their units to attain standards. The STRAC strategies are models for training and resourcing and represent *one way* to attain and sustain standards. Because they are generic and notional, they do not generate specific requirements. Commanders can select from a generic menu of training events that allows them to train towards a specific assigned mission or training goal. This flexibility is intended to accommodate unit requirements.

C-3. Training strategy tables reflect generic requirements. They do not automatically translate into resource authorizations or allocations of rounds on the ground to be fired. Factors affecting annual authorizations for training ammunition include:

- STRAC strategies.
- Budgetary constraints.
- Unit priority.
- Historical expenditures.
- War reserves.

C-4. DA Pams 350-38 and 350-39 contain requirement computation data for training ammunition. Figures are based on the number of weapons systems assigned, readiness levels, and quantities of ammunition needed to sustain soldier and crew proficiency. They apply to the weapon and weapon systems used throughout the force for both the Active and Reserve Components. These pamphlets provide commanders and other unit trainers with a common set of standards for weapon and weapon system qualification. Also, they offer suggested weapons training strategies, a model for resource requirements, and measurable standards for evaluating overall training readiness.

FORECASTING

C-5. Forecasting ammunition requirements is a peacetime procedure. It is based on data in the pamphlets cited above and on projected training events such as individual weapons qualification, FTXs, and crew weapons qualification. Factors that impact requirements-determination forecasting include the following:

- Historical and actual ammunition consumption data from previous training exercises.
- Training objectives.
- Equipment/weapon system availability.
- Range time.

C-6. Training ammunition requirements are determined using DA Form 5514-R. This document summarizes the total quantity of each DODIC needed to support training during the coming 12 months. As prescribed by AR 5-13, MACOMs modify and provide requirements to HQDA before the beginning of each fiscal year. HQDA gives MACOMs the authorization for training ammunition based on stock availability, funding, ammunition production, transportation, and other considerations. Units prepare and use this forecast to maintain an up-to-date calculation of ammunition needs. MACOMs use it to determine requisition needs. This forecast also feeds the WARS.

C-7. To get ammunition for training, units must prepare training ammunition forecasts IAW DA Pam 710-2-1 and submit them as directed by the MACOMs. Time frames for submitting forecasts also are prescribed by the MACOMs. Generally, the procedure is as follows:

- Determine planned training requirements for each of the next 12 months.
- Determine the DODIC and quantity needed for each training requirement. Refer to the computation data in DA Pams 350-38 and 350-39.
- Do not exceed a quantity when that quantity remains on the authorized allocation for the current fiscal year.
- Coordinate with the S3/S4, G4, or DOL to ensure that quantities forecast are not excessive and that the correct historical data were used when computing requirements for months in the next fiscal year.
- Use DA Form 5514-R to record the total for each DODIC required for each month in which the unit will draw training ammunition from an ASA.
- Submit the completed forecast to the next higher headquarters.

Each level in the chain of command uses DA Form 5514-R to consolidate and forward the forecasts to the next higher headquarters IAW means prescribed by the MACOM.

MANAGING

C-8. Units that request and receive ammunition from an ASA must maintain training ammunition management and control documents. Use the documents listed below to manage training ammunition and missile authorizations, to control issue of ammunition and missiles, and to ensure that unexpended ammunition and ammunition residue are controlled until returned to the ASA:

- DA Form 5203.
- DA Form 5204.
- DA Form 581 or automated equivalent.
- DA Form 581-1.
- DA Form 3151-R.
- DA Forms 5515 and 5515-1.
- DA Form 2064.

The TAMIS Authorization Report is used to maintain a running balance of the annual training authorization by deducting, from the initial authorization, issues from the ASA. The G-3 or installation DOL usually manages this computer-based report.

PHYSICAL SECURITY AND AMNESTY PROGRAMS

C-9. Upon departure from the ASA, the receiving unit must provide physical security for ammunition IAW AR 190-11 and DA Pam 710-2-1. At the discretion of their MACOMs, AC and ARNG units located OCONUS are authorized home storage of training ammunition. The same storage and inventory procedures that apply to basic load ammunition apply to training ammunition. Also, AR 190-11 outlines construction requirements for ammunition storage rooms and magazines, and DA Pam 710-2-1 provides guidance on field storage and use of residue items for training.

C-10. Installation commanders will establish and implement an amnesty program that does not intimidate the individual or prevent the individual from freely turning in ammunition. The intent of amnesty programs is to ensure maximum recovery, not to circumvent normal turn-in procedures. Commanders will monitor amnesty programs as indicators of effectiveness of ammunition accountability and ensure that they are not used to circumvent accountability. See DA Pam 710-2-1 for more guidance on establishing an amnesty program.

Appendix D

Brass Conversion

The data and procedures contained in this appendix are used to compute the weight and/or quantity of expended cartridge cases. See Figure D-1 below.

Case Type	Weight (pounds)
.22 caliber, brass, short	.0008
.22 caliber, brass, long	.0014
.30 caliber, brass, carbine	.0101
.30 caliber, steel, carbine	.0081
.30 caliber, brass, all others	.0286
.38 caliber, brass, all	.009
.45 caliber, brass, all	.0124
.45 caliber, steel, all	.012
.50 caliber, brass, all	.121
.50 caliber, steel, all	.111
5.56 millimeter, brass, all	.0135
7.62 millimeter, brass, large	.026
9 millimeter parabellum	.009
20.0 millimeter, brass, small	.2
20.0 millimeter, brass, large	.25
25 millimeter, all	.48
Shotgun, brass, all	.036

Figure D-1. Brass Conversion Chart

TO FIND WEIGHT

D-1. Multiply the quantity of expended cartridge cases by the weight. Using the example, brass, short, expended-rounds, .22 caliber, work the formula as shown below.

FORMULA

D-2. Quantity of the item x Weight = Weight of expended cartridge cases.

COMPUTATION

D-3. 39,875 rounds x .0008 lbs = 31.9 lbs.
Work to one decimal place and round down: 31 pounds expended.

TO FIND QUANTITY

D-4. Divide the weight of the expended cartridge cases by the weight. Using the example, brass, expended-cartridges weight of .38 caliber, work the formula as follows:

FORMULA

D-5. Total Weight ÷ Weight of the item = Quantity of expended cartridge cases.

COMPUTATION

D-6. 82.0 pounds ÷ .009 pounds = 9,111.1 rounds.
Work to one decimal place and round down: 9,111 rounds.

Appendix E

Ammunition Condition Codes

Ammunition condition codes are single letters that classify munitions materiel. Each ACC identifies degree of serviceability, condition, and completeness (readiness for issue and use), as well as actions under way to change the status of materiel. This appendix defines ACCs A-H, J-N, and P.

ACC A–SERVICEABLE (ISSUABLE WITHOUT QUALIFICATION)

E-1. New, used, repaired, or reconditioned materiel that is serviceable and issuable to all units without limitations or restrictions. This includes materiel with more than six months shelf life remaining.

E-2. Normal incidental requirements for additional packaging, packing, marking, and so forth that can be accomplished at the time of issue (without requiring added resources, manpower, or delays) do not constitute a restriction.

ACC B–SERVICEABLE (ISSUABLE WITH QUALIFICATION)

E-3. New, used, repaired, or reconditioned materiel that is serviceable and issuable for its intended purpose; however it is restricted from issue to specific units, activities, or geographical areas by reasons of its limited usefulness or short-service life expectancy. This includes materiel with three through six months shelf life remaining.

E-4. Normal incidental requirements for additional packaging, packing, or marking, and so forth that can be accomplished at the time of issue (without requiring any added resources, manpower, or delays) do not constitute a restriction. This includes items restricted to or from a specific mission.

ACC C–SERVICEABLE (PRIORITY OF ISSUE)

E-5. Items that are serviceable and issuable to selected customers, but that must be issued before conditions A and B materiel to avoid loss as usable assets. Includes materiel with less than three months shelf life remaining.

ACC D–SERVICEABLE (TEST/MODIFICATION)

E-6. Serviceable materiel requiring test, alteration, modification, conversion, or disassembly. This does not include items that must be inspected or tested immediately before issue.

ACC E–UNSERVICEABLE (LIMITED RESTORATION)

E-7. Materiel that involves only limited expense or effort to restore to serviceable condition and is accomplished in the ASA where the stock is located. Minor maintenance is exterior to the round or munitions. Includes all repair of external surfaces and repair/replacement of packaging, packing, palletizing, and marking.

ACC F–UNSERVICEABLE (REPARABLE)

E-8. Economically reparable materiel that requires repair, overhaul, or reconditioning. Includes reparable items that are radioactively contaminated. Major maintenance usually requires replacement of end item components or modification.

ACC G–UNSERVICEABLE (INCOMPLETE)

E-9. Materiel requiring additional parts or components to complete the end item prior to issue.

ACC H–UNSERVICEABLE (CONDEMNED)

E-10. Material that has been determined to be unserviceable and does not meet repair criteria (includes condemned items that are radioactively contaminated). This includes materiel determined to be uneconomically repairable.

ACC J–SUSPENDED (IN STOCK)

E-11. Materiel in stock that has been suspended from issue and use pending condition classification or analysis, where the true condition is not known.

E-12. Includes temporarily suspended materiel pending serviceability determination. Includes USAF materiel identified and held for future test or surveillance requirements, either destructive or nondestructive in nature. May contain formerly serviceable assets that became unserviceable by reason of being reserved for test or that the shelf/service life has expired. Army ammunition that has missed two scheduled periodic inspections is included.

ACC K–SUSPENDED (RETURNS)

E-13. Materiel returned from users and awaiting condition classification. Includes items identified by stock number and item name, but not examined for condition. Stocks in this ACC will be inspected and properly classified as to condition IAW appropriate regulations. When more time is required, an extension may be granted by the applicable supply distribution activity.

ACC L–SUSPENDED (LITIGATION)

E-14. Materiel held pending litigation or negotiation with contractors or common carriers.

ACC M–SUSPENDED (IN WORK)

E-15. Materiel identified on inventory control records, but which has been turned over to a maintenance facility or contractor for processing.

ACC N–(SUITABLE FOR EMERGENCY COMBAT USE)

E-16. Munitions stocks suspended from issue except for emergency combat use.

ACC P–UNSERVICEABLE (RECLAMATION)

E-17. Materiel determined to be unserviceable, uneconomically reparable due to a physical inspection, tear-down, or engineering decision. Items contain serviceable components or assemblies to be reclaimed.

Appendix F

Ammunition Identification

Ammunition is identified by markings and color-coding on the items themselves, the containers, and the packing boxes. The markings and standard nomenclature of each item, together with the lot number, FSC, NSN, DODIC, and DODAC, completely identify each item and are used to maintain accountable records. This appendix gives a basic explanation of markings and color-coding. Because color-coding is a more ready means of identification, it is given greater emphasis here.

MARKINGS

F-1. Markings stenciled or stamped on munitions items include all information needed for complete identification. Components in which all explosive, incendiary, or toxic materials have been simulated by substitution of inert material are identified by impressed INERT markings. Components in which all explosive, incendiary, or toxic materials have been omitted are identified by stamped EMPTY markings.

AMMUNITION LOT NUMBER

F-2. Each item of ammunition is assigned a complete round or item lot number when it is manufactured or is at the LAP plant. See MIL-STD 1168-A for a description of the current system. See MIL-STD 1168 for a discussion of the old lot numbering system. Figure F-1 breaks down a typical ammunition lot number showing both the new and old systems.

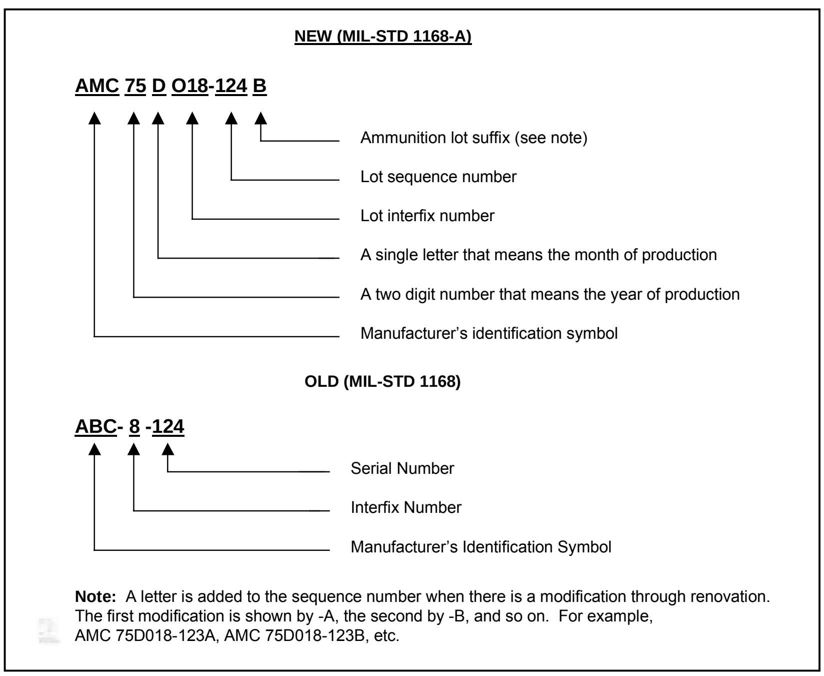


Figure F-1. Typical Lot Number System

CONVENTIONAL AMMUNITION FEDERAL SUPPLY CLASSES

F-3. Conventional ammunition is FSG 13. Within this group, ammunition is further broken down by two more numbers that identify the general type or family in which the item falls. Table F-1 lists the FSCs.

Table F-1. FSC Group 13 Classes

FSC Group 13 (classes)	Ammunition and Explosive Type or Family
1305	Ammunition, through 30mm
1310	Ammunition, over 30mm up to 75mm
1315	Ammunition 75mm through 125mm
1320	Ammunition, over 125mm
1330	Grenades
1340	Rockets and rocket ammunition
1345	Land mines
1365	Military chemical agents
1370	Pyrotechnics
1375	Demolition materials
1376	Bulk explosives
1377	Cartridge and propellant actuated devices and components
1390	Fuzes and primers
1395	Miscellaneous ammunition
1398	Specialized ammunition handling and servicing equipment
1410/20/25/27	Guided missiles
Note: There are other FSC groups, but they are for Class V materiel outside the US Army ammunition inventory. (Look in any current copy of the DOD ammunition listing, volumes 1 through 3, for more information.)	

CONVENTIONAL AMMUNITION NATIONAL STOCK NUMBERING SYSTEM

F-4. Each complete round or item of conventional ammunition or associated explosive component is identified by its own NSN. The first four numbers of the NSN is the FSC. It is followed by the National Item Identification Number, or NIIN, which consists of a two-number code identifying the country of manufacture and a seven-number item identification. See Figure F-2 below.

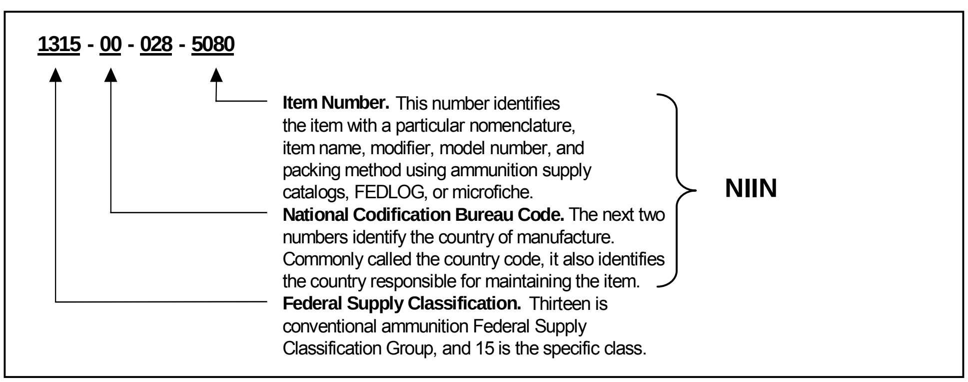


Figure F-2. Example of an NSN

DEPARTMENT OF DEFENSE IDENTIFICATION CODE

F-5. A DODIC is a single letter and three numbers or, in the case of small guided missiles, two letters and two numbers. It is attached at the end of all NSNs to denote interchangeability of the item. Communications between ammunition units often use an ammunition item DODIC. See Figure F-3 for a conventional NSN with DODIC added, demonstrating interchangeability between various model numbers and the designators of an ammunition item.

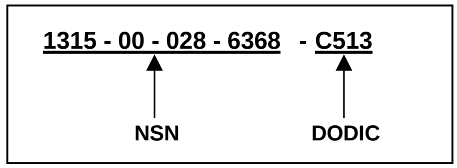


Figure F-3. Sample DODIC

DEPARTMENT OF DEFENSE AMMUNITION CODE

F-6. The DODAC includes the FSC of the ammunition and the DODIC. The code is used on all using unit DD Form 581s, DA Form 3151-Rs, and most ammunition reports. The DODAC is used instead of the DODIC to reduce errors with ammunition transactions. See Figure F-4.

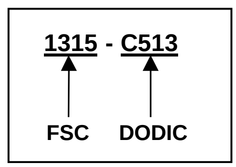


Figure F-4. Example of a DODAC

COLOR CODING

F-7. The main reason ammunition is painted is to protect it from rust. However, the color of the protective coating and markings also makes ammunition easy to identify and provides some camouflage. Ammunition 20mm and larger is color-coded IAW MIL-STD 709C (see Tables F-2 and F-3). Figure F-5 shows typical markings for an artillery round of ammunition.

F-8. Small arms ammunition is not color-coded under MIL-STD 709C. Either the small arms projectiles or the bullet tips are painted a distinctive color so they can be identified quickly. Figures F-6 through F-8, pages F-7 through F-9, show the color codes for types of small arms ammunition up to and including.50 caliber. For more information, see TM 9-1300-200. Significant features of the current color-coding standard are as follows:

- **Olive drab.** With yellow markings, OD indicates an HE round. However, OD is also being used as a basic color for certain new rounds such as ICMs, the flechette antipersonnel round, and some new illumination rounds for specific field artillery weapons.
- **Overpacking.** Ammunition overpacked in color-coded bombs, in unit dispensers, or in warheads, must not be color-coded.

- **Camouflage.** Ammunition containing toxic chemical, incapacitating, or riot control chemical agents must never be camouflaged by painting.
- **Standard DOD Ammunition Color Code.** MIL-STD 709C contains the standard ammunition color code for 20mm and larger ammunition. Be aware, though, that there is still ammunition coded as specified by MIL-STD 709-B and MIL-STD 709-A. If this is the case, see the appropriate MIL-STD or TM 9-1300-200.

Table F-2. Ammunition Color Code, MIL-STD 709C

Color[1,2]	Fed Std No 595	Interpretation
Yellow	33538	Identifies HE ammunition or indicates presence of HE.
Brown	30117 or 30140	Identifies low-explosive items of components or indicates low explosive. Normally brown band around the item.
Gray[3,4]	36231	Identifies chemical ammunition containing toxic chemical, incapacitating or riot control agent. Used as basic color.
Dark red	31136	Identifies riot control agent filler.
Dark green[3]	34108	Identifies toxic chemical agent filler. Used for markings and bands.
Violet	17100	Identifies incapacitating agent filler. Used for markings or bands.
Black[3,5]	37038	Identifies armor-defeating ammunition or indicates armor-defeating capability.
Silver/aluminum	17178	Identifies countermeasure ammunition (e.g., radar echo, leaflets).
Light green[3]	34558 or 34449	Identifies screening or marking smoke ammunition.
Light red	31158	Identifies incendiary ammunition or indicates highly flammable material (liquids, jellies, solids) that produce damage by fire.
White[3,5,6]	37875	Identifies illuminating ammunition or ammunition that produces a colored light.
Light Blue	35109	Identifies practice ammunition.
Orange	32246	May be used to identify ammunition used for tracking and recovery in tests or training operations (e.g., underwater mines and torpedoes).
Bronze, gold, brass	17043	Identifies completely inert ammunition for use in activities such as assembly, testing, handling, drills, etc., not to be delivered in a delivery system.

Footnote. The following have no color-coding significance:

1. Colors specifically applied to identify the color of smoke ammunition or pyrotechnics.
2. Unpainted or natural color ammunition.
3. Gray black, green, or white on underwater ammunition.
4. Gray on air-launched missiles.
5. Black or white when used for lettering or special marking.
6. White on guided missiles, dispensers, and rocket launchers.

Table F-3. Application of Color Codes for Particular Ammunition Items, MIL-STD 709C

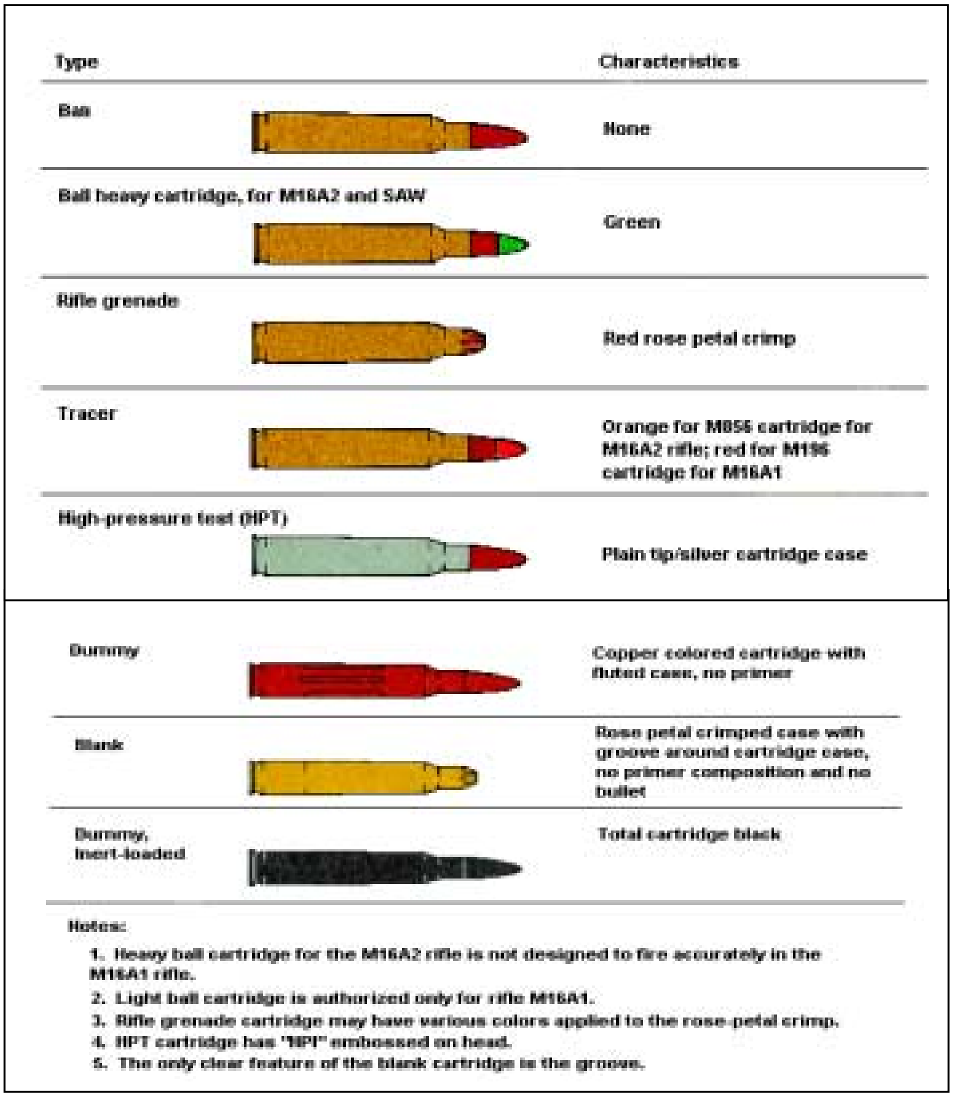
Ammunition	Colors		
	Body	Markings [1]	Bands
HE, except 20mm	Olive drab	Yellow	Yellow [2,3,4,5]
HE, 20mm	Yellow	Black	None
Explosive binary munitions	Olive drab	Yellow	Broken yellow[6]
HEP	Olive drab	Yellow	Black
HEAT	Black	Yellow	None
Antipersonnel and antitank mines	Olive drab	Yellow	Yellow[3]
Incendiary	Light red	Black	None
HEI	Yellow	Black	Light red
API	Black	White	Light red
AP			
With bursting charge	Black	Yellow	None
Without bursting charge	Black	White	None
Canister	Olive drab	White	None
Flechette-loaded	Olive drab	White	White[7] Yellow[8]
Chemical			
Filled with a toxic chemical binary nerve agent	Gray	Dark Green	One broken dark green[9,10,11]
Illuminating			
Separate loading	Olive drab	White	White
Fixed or semifixed	White	Black	None
Practice			
With low explosive to indicate functioning			Brown
With high explosive to indicate functioning			Yellow
Without explosive to indicate functioning			None
Screening or marking			
Smoke ammunition			
Filled with other than WP	Light green	Black	None
Filled with WP	Light green	Light red	Yellow[9] Light red[12]
Inert ammunition not designed to be delivered in a delivery system	Bronze	Black	None
Chemical			
Filled with a riot control agent	Gray	Red	One red[9]
Filled with an incapacitating agent	Gray	Violet	One violet[9]
Filled with a toxic chemical agent other than binary agents	Gray	Dark Green	One dark green[9]
Filled with a toxic chemical binary nerve agent	Gray	Dark Green	One broken dark green [9,10]

Table F-3. Application of Color Codes for Particular Ammunition Items, MIL-STD 709C (Continued)

Footnotes:

1. Color of the letters and figures normally used for the main identification.
2. Circumferential band of yellow diamond-shaped figures on semifixed and separate-loading improved conventional munitions.
3. Circumferential band of yellow triangular-shaped figures on mass scatterable mine and loaded semifixed and separate-loading ammunition.
4. Separate-loading ammunition for shipboard use has a circumferential yellow band besides yellow markings.
5. Bombs have one yellow band except thermally protected bombs, which have two yellow bands besides yellow markings.
6. Circumferential broken yellow band (1/2-inch segments with 1/2-inch gaps) on explosive binary munitions.
7. Circumferential band of white diamond-shaped figures on ammunition containing flechettes.
8. Yellow band put on when the ammunition contains explosives used to fracture the projectile.
9. Yellow band put on to indicate HE burster.
10. Toxic chemical agent ammunition containing a binary nerve agent filling shown by a broken dark green band (1/2-inch segments separated by 1/2-inch spaces).
11. Both color applications are standard. However, for land ammunition use, separate-loading ammunition is olive drab for overall body color with a white band and main identification details marked white. Fixed and semifixed ammunition is white for overall body color with main identification details in black.
12. Separate-loading ammunition for shipboard use has black markings and a light red band.

Figure F-5. Typical Artillery Markings

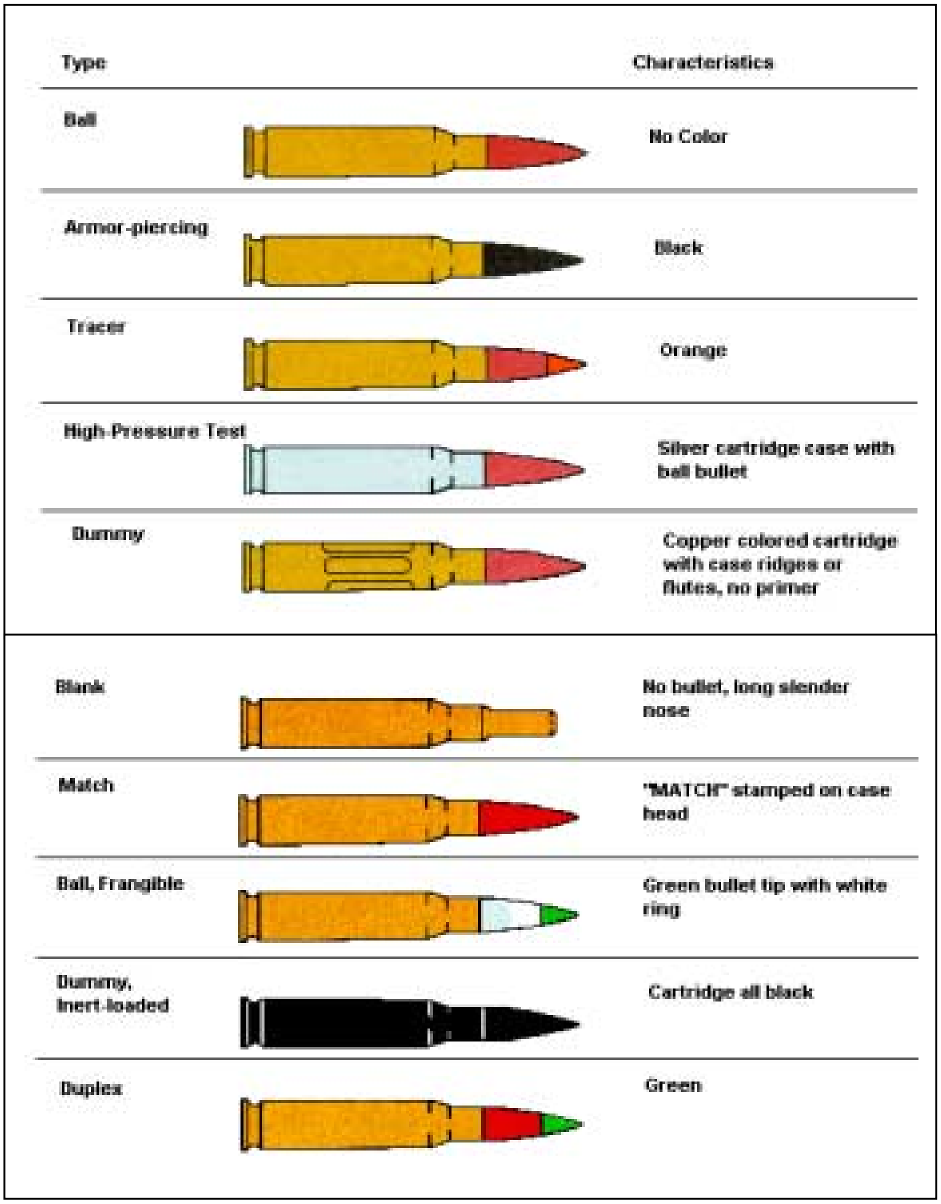


Type	Characteristics
Ball	None
Ball heavy cartridge, for M16A2 and SAW	Green
Rifle grenade	Red rose petal crimp
Tracer	Orange for M856 cartridge for M16A2 rifle; red for M196 cartridge for M16A1
High-pressure test (HPT)	Plain tip/silver cartridge case
Dummy	Copper colored cartridge with fluted case, no primer
Blank	Rose petal crimped case with groove around cartridge case, no primer composition and no bullet
Dummy, inert-loaded	Total cartridge black

Notes:

1. Heavy ball cartridge for the M16A2 rifle is not designed to fire accurately in the M16A1 rifle.
2. Light ball cartridge is authorized only for rifle M16A1.
3. Rifle grenade cartridge may have various colors applied to the rose-petal crimp.
4. HPT cartridge has "HPT" embossed on head.
5. The only clear feature of the blank cartridge is the groove.

Figure F-6. 5.56mm Cartridges



Type	Characteristics
Ball	No Color
Armor-piercing	Black
Tracer	Orange
High-Pressure Test	Silver cartridge case with ball bullet
Dummy	Copper colored cartridge with case ridges or flutes, no primer
Blank	No bullet, long slender nose
Match	"MATCH" stamped on case head
Ball, Frangible	Green bullet tip with white ring
Dummy, Inert-loaded	Cartridge all black
Duplex	Green

Figure F-7. 7.62mm Cartridges

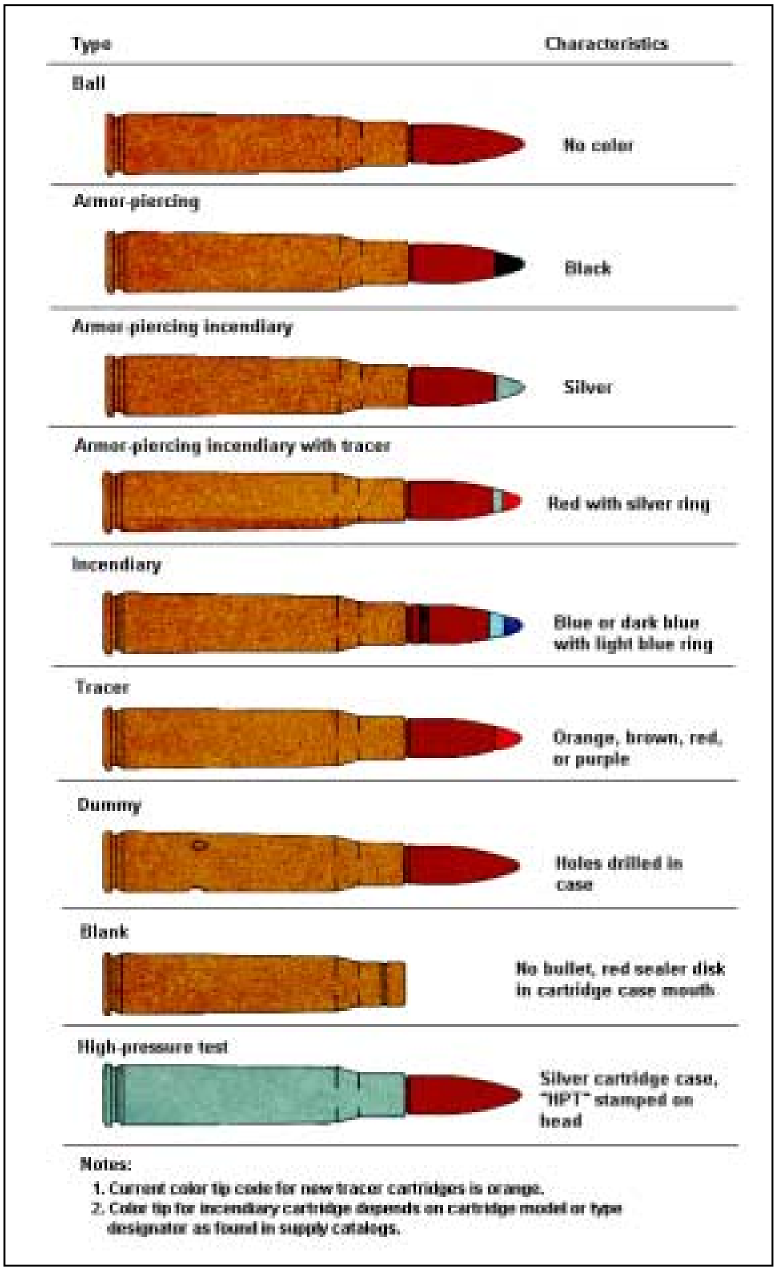


Figure F-8. Caliber .50 Cartridges

Appendix G

Movement Control and Types of Transport

This appendix provides an overview of the responsibilities of movement control organizations. It addresses the importance of these organizations in ensuring that munitions are efficiently moved at the right time and place. Although modular munitions platoons or companies may not always be directly involved in movement control, they depend on an effective transportation system for receipt and shipment of munitions. At times, unit personnel may work directly with movement control teams in coordinating munitions shipments.

OVERVIEW

G-1. In a force projection environment, the employment of military ground forces and combat power decides the outcome of campaigns and operations. The success of these forces often depends on sound, timely deployment and sustainment support. A well defined, integrated transportation system is fundamental to the success of these operations. Movement control is one of the most critical functions of the transportation system. It contributes significantly to the success or failure of any operation. Effective movement control of forces, units, and logistics (particularly munitions) enhances combat effectiveness. Inadequate control results in waste, reduced efficiency, and loss of potential combat power. Movement control incorporates the following actions:

- Planning.
- Validating.
- Allocating.
- Routing.
- Coordinating.
- Force tracking.
- Priority management.
- In-transit visibility.

Also, movement control is the commitment of apportioned transportation assets according to command directives.

THEATER DISTRIBUTION

G-2. Theater distribution involves a fully integrated distribution management system that uses technology, doctrine, and procedures to enhance distribution operations. Effective distribution management coordinates the various sub-elements of the following distribution equation:

- Transportation elements of movement control, mode operations, and terminal and cargo transfer operations.
- Materiel management.

- Supply support.

Movement control is key to developing the distribution plan. Movement programming, highway regulation, and the establishment of movement control interfaces throughout the distribution structure are all critical to the success of the theater distribution plan.

G-3. One of the major tasks of the TSC is development of the theater distribution plan to support the theater commander's intent and concept of operation. This plan fuses transportation and materiel into one system, incorporating RSO&I and sustainment operations. The distribution system is a complex of networks, facilities, procedures, arrangements, and units. The unit's responsibility is to receive, store, maintain, issue, and move materiel, personnel, and equipment.

G-4. The distribution system functions along LOCs that take into account transportation assets and geography of the theater and area of operations. Throughput is a function of the transfer capacity of key nodes along the LOC. Nodes are locations where a materiel or unit movement requirement is originated, processed for onward movement, and transferred to another transport node or terminated. Nodes and LOC security are essential to an effective distribution plan. Nodes for materiel and munitions movements include the SPOD, APOD, TSA, CSA, ASP, and ATP.

MOVEMENT CONTROL INTERFACE

G-5. An effective distribution system requires continuous coordination between materiel and movement control personnel and organizations at every level of command. During the movement program planning process, planners allocate available transportation resources to support requirements based on the commander's priorities. Logisticians at each level are responsible for implementing these priorities. The functions of the movement program are as follows:

- Establishes which requirements can be resourced given available transportation assets, units, and infrastructure.
- Serves as the authority for committing transportation assets.
- Authorizes MCTs to issue TMRs.
- Directs mode operators to furnish assets.
- Alerts receiving units to accept programmed shipments so they can unload transportation assets promptly.

G-6. Planners must be flexible because requirements often change to accommodate changes in priority, unit locations, asset availability, and conditions of the LOCs. Planners coordinate with the TSC and COSCOM regarding the positioning of transportation units and supply activities. Also, they coordinate with shippers and receivers to determine their capability to receive, handle, and load by various transportation nodes. This capability is based on the availability of MHE, CHE, ramps, labor, storage capacity, and other factors that effect transportation services.

MOVEMENT CONTROL ORGANIZATIONS

G-7. The organizations discussed in this section are representative of those involved in the movement of munitions. All units in the munitions support structure must have an understanding of the movement process in the theater of operations and of the responsibilities of these organizations.

MOVEMENT CONTROL AGENCY

G-8. The MCA provides movement management services for all common user transportation nodes, including allied/HN assets when they are committed to support the theater logistics or transportation plan. The MCA performs the following functions:

- Monitors daily transportation movement requirements and capabilities.
- Implements the task force commander's priorities.
- Supervises movement control battalions (EAC).
- Develops and enforces theater highway regulations.

The MCA is a modularly designed organization and is assigned to a TSC.

MOVEMENT CONTROL BATTALION (EAC)

G-9. The MCB (EAC) commands, controls, and supervises MCTs; controls the movement of all personnel, units, and materiel in the theater; and maximizes the use of available transportation assets. It is assigned to a TSC and is normally attached to the MCA. The battalion commands and controls MCTs *behind* the corps rear boundary. It provides asset visibility and maintains ITV of tactical and nontactical moves within the MCA defined geographical area.

MOVEMENT CONTROL BATTALION (CORPS)

G-10. The corps MCB commands and controls MCTs *forward* of the corps rear boundary. It is assigned to a corps and plans, coordinates, and manages movement programming, highway regulation, and transportation support for the corps. The corps MCB provides asset visibility and maintains ITV of tactical and nontactical moves within the corps defined geographical area.

PORT MCT

G-11. The port MCT expedites, coordinates, and supervises transportation support of units, cargo, and personnel into, through, and out of air, land, or water ports (with the exception of bulk POL using a pipeline). The port MCT is assigned to a corps, ASCC, or TSC and is normally attached to an MCB (EAC or corps). It expedites the throughput of cargo through the transportation system and provides ITV of units, cargo, and personnel transiting from/to PODs/POEs. This MCT deploys on an as-needed basis, supporting onward movement and sustainment operations.

AREA MCT

G-12. The area MCT expedites, coordinates, and supervises transportation support of units, cargo, and personnel into, through, and out of air, land, or water ports. It supports inland transfer points and supply support activities. It expedites cargo throughput and provides ITV of units, cargo, and personnel moving through an assigned geographic area. The area MCT is assigned to a corps, ASCC, or TSC and is normally attached to an MCB (corps or EAC).

DIVISION SUPPORT MCT

G-13. The division support MCT augments the DTO. It assists the DTO with movement programming, highway regulation, and division transportation support. It assists in executing divisional highway regulation for nontactical movements and planning and coordinating division MSRs. Also, the division support MCT provides movement control for tactical and nontactical road marches. It is assigned to a corps and attached to a division.

MOVEMENT REGULATING CONTROL TEAM

G-14. The MRCT operates up to four separate movement regulating points. It is assigned to a corps, ASCC, or TSC and is attached to a MCT (corps or EAC). The MRCT operates on MSRs and other designated controlled routes to regulate convoys and serve as the eyes and ears of the MCB. Based on mission requirements, the unit deploys on an as-needed basis.

CARGO DOCUMENTATION TEAM

G-15. The CDT provides cargo documentation for the transshipment of cargo in water, air, motor, and rail terminals. It is assigned to a corps, ASCC, or TSC and is attached to an MCB (corps or EAC).

TYPES OF TRANSPORT

G-16. A major activity of most munitions units is loading trucks, railcars, and aircraft. The planning and execution of the loading process generally requires some knowledge of the types of transport and their capabilities.

MOTOR

G-17. Motor transport is the backbone of the Army's support and sustainment structure, providing mobility on and off the battlefield. Motor transport operations support a variety of missions depending on unit locations and situations. Motor transport units are usually employed for general support within a specified area or along specific routes. Most munitions units are actively engaged in shipping operations where the capacity of different types of vehicles must be known. Refer to Table G-1 for cargo cube and weight data. For more detailed information, see Chapter 3 of FM 55-15. This chapter contains current mechanical data on authorized motor transport vehicles, including axle weights; truck performance data; center of balance data for single-unit trucks; and dimensions and capacities for prime movers and towed vehicles.

AIR

G-18. Airlift is a flexible and essential element of the transportation system. Army aviation units support theater, corps, and division requirements. The aviation brigade is the Army's primary aviation unit and is found at EAC, corps, and division. Army airlift is not intended to compete with Air Force airlift. Its purposes are rapid response for high-priority personnel, supplies, and equipment and to supplement the lift capability of other Army transportation systems. Army airlift is essential to the logistic support of Army operations. There are only three approved methods of external air transport: slings, cargo nets, and cargo bags. Data on load capacities and configurations of current Army aircraft are found in FM 55-15, Chapter 2.

RAIL

G-19. Different classification systems exist for locomotives in CONUS and most other countries throughout the world. Information to include characteristics of locomotives, capacities of different types of railcars, maximum load data, and track gauges of the world can be found in FM 55-15, Chapter 4.

Table G-1. Cargo Cube and Weight

Vehicle	Payload in Lbs Weight in Parentheses = Towed Payload	Note(s)	Length in Inches	Width in Inches	Height (1) in Inches	Cube in Feet
Truck, cargo, 1 ¼ T, 4X4, M998	2,500 (3,400)					
Truck, cargo, 1 ¼ T, 4X4, M1097	4,400 (4,200)					
Truck, utility, ¾ T, 4X4, M1009	1,200 (3,000)	1				
Truck, cargo, 1 ¼ T, 4X4, M1008	2,900 (3,000)					
Truck, cargo, 1 ¼ T, 4X4, M1028	3,600 (3,000)					
Truck, cargo, 2 ½ T, 6X6, M35A1, A2	5,000 (6,000)	4	146.8	88	60	441.9
Truck, cargo, 2 ½ T, 6X6, M35A2C	5,000 (6,000)	4	147	87.6	60	440.5
Truck, cargo, 2 ½ T, 6X6, M36A2	5,000 (6,000)	4	210	88	71.8	759.3
Truck, dump, 2 ½ T, 6X6, M342A2	5,000 (6,000)		130	70	24.5	273.8
Truck, tractor, 2 ½ T, 6X6, M275A2	(17,000)	2				
Truck, dump, 5 T, 6X6, M51, M51A2	10,000 (15,000)		123	82	25	297.6
Truck, dump, 5 T, 6X6, M817, M929	10,000 (15,000)		124.8	81.9	27.1	306.3
Truck, dump, 5 T, 6X6, M929A1, M930A1, M931	10,000 (15,000)					

Table G-1. Cargo Cube and Weight (Continued)

Vehicle	Payload in Lbs Weight in Parentheses = Towed Payload	Note(s)	Length in Inches	Width in Inches	Height (1) in Inches	Cube in Feet
Truck, tractor, 5 T, 6X6, M52, M52A1	(30,000)	2				
Truck, tractor, 5 T, 6X6, M52A2	(37,000)					
Truck, tractor, 5 T, 6X6, M818, M931A1, M931A2, M932A1	(37,500)	2, 3				
Truck, cargo, 5 T, 6X6, M54, M54A1	10,000 (15,000)	6, 7	168	88	60	480.2
Truck, cargo, 5 T, 6X6, M54A1C	10,000 (15,000)	6, 7	168	88	60	482.5
Truck, cargo, 5 T, 6X6, M54A2	10,000 (15,000)	6, 7	168	88	61	480.2
Truck, cargo, 5 T, 6X6, M54A2C	10,000 (15,000)	6, 7	168	88.4	60	482.5
Truck, cargo, 5 T, 6X6, M55, M55A2	10,000 (15,000)	8	244	88	61.3	751.5
Truck, cargo, 5 T, 6X6, M813	10,000 (15,000)	8, 9	168	88.3	57.2	468
Truck, cargo, 5 T, 6X6, M813A1	10,000 (15,000)	8, 9	168	88.3	57.4	468
Truck, cargo, 5 T, 6X6, M814	10,000 (15,000)	8	243.8	87.8	60	733
Truck, cargo, 5 T, 6X6, M923, M923A1, M923A2, M925, M925A1, M925A2, M927, M927A1, M927A2, M928, M928A1, M928A2	10,000 (15,000)	8, 9	168	88.3	57.4	468
Truck, cargo, 10 T, 8X8, M977	22,000 (20,000)	10, 11	216	90	48	540
Truck, cargo, 10 T, 8X8, M978	18,000 (20,000)					
Truck, cargo, 10 T, 8X8, M985	21,729 (20,000)	11	216	90	48	540
Truck, cargo, 10 T, 8X8, M984	31,000 (20,000)					
Truck, tractor, 10 T, 6X6, M916	(126,000)	2				
Truck, tractor, 10 T, 6X6, M916A1	(130,000)	2				

Table G-1. Cargo Cube and Weight (Continued)

Vehicle	Payload in Lbs Weight in Parentheses = Towed Payload	Note(s)	Length in Inches	Width in Inches	Height (1) in Inches	Cube in Feet
Truck, tractor, 10 T, 6X6, M920	(99,620)	2				
Truck, tractor, 10 T, 6X6, M123A1C	(80,000)	2				
Truck, tractor, 14 T, 6X6, M915, M915A1	(84,000)	2				
Truck, tractor, 14 T, 6X6, M915A2	(105,000)	2				
Truck, tractor, 16.5 T, 10X10, PLS, M1074	33,000 (50,000)					
Truck, tractor, 16.5 T, 10X10, PLS w/crane, M1075	33,000 (50,000)					
Truck, cargo, 2 ½ T, 4X4, FMTV (LMTV), M1078, LAPES M1081	5,000 (9,520)		144	95		
Truck, cargo, 5 T, 6X6, FMTV M1083, w/MHE M1084	10,000 (21,000)		168	95		
Truck, cargo, 5 T, 6X6, FMTV, M1085, w/MHE M1086	10,000 (21,000)		240	95		
Truck, tractor, 5 T, 6X6, FMTV, M1088	(25,000)					
Truck, dump, 5 T, 6X6, FMTV, M1090	10,000 (21,000)					135
Truck, cargo, 5 T, 6X6, FMTV, LAPES/AD, M1093	10,000 (21,000)		168	95		
Truck, dump, 5 T, 6X6, FMTV, LAPES, M1094	10,000 (21,000)					135

Notes:
1. Highway requirements only
2. Towed load is the total weight of the semitrailer and payload.
3. Vehicles approved for use with M871 semitrailer carrying loads up to 44, 800 pounds.
4. Cubic capacity reduced 6.6 cubic feet for curve of bows.
5. Cubic capacity reduced 8.8 cubic feet for curve of bows.
6. Cubic capacity reduced 26.1 cubic feet for spare tire and carrier in cargo body.
7. Cubic capacity reduced 7.0 cubic feet for curve of bows.
8. Cubic capacity reduced 10.2 cubic feet for curve of bows.
9. Cubic capacity reduced 14.5 cubic feet for spare tire and carrier in cargo body.
10. Cubic capacity reduced 27.0 cubic feet for spare tire and carrier in cargo body.
11. Cube measured to top of spare tire.

Appendix H

Hazardous Materials Information

This appendix consists primarily of charts that provide data required to prepare munitions shipments. As always, safety is a primary consideration when handling, processing, and transporting munitions. See DOD 4500.9-R and Title 49, Code of Federal Regulations, Part 172, for more information.

UNO AMMUNITION AND EXPLOSIVES SHIPMENTS

H-1. Tables H-1 through H-3 contain the elements of UNO information required to prepare munitions for shipment and to complete required forms. PSNs are limited to those shown in regular type (not italic type). PSNs may be used in the singular or plural and in either capital or lower-case letters. Although punctuation marks and words in italics are not part of the PSN, they may also be included. The word "or" in italics indicates that terms in the sequence may be used as the PSN, as appropriate. These elements are established by and defined in 49 CFR.

Table H-1. UNO HC 1 Requirements Data

UNO Number	Proper Shipping Name	HC/DIV with SCG
0004	Ammonium picrate, *dry or wetted with less than 10 percent water by mass*	1.1D
0005	Cartridges for weapons, *with bursting charge*	1.1F
0006	Cartridges for weapons, *with bursting charge*	1.1E
0007	Cartridges for weapons, *with bursting charge*	1.2F
0009	Ammunition, Incendiary *with or without burster, expelling charge, or propelling charge*	1.2G
0010	Ammunition, Incendiary *with or without burster, expelling charge, or propelling charge*	1.3G
0012	Cartridges for weapons, inert projectile *or* Cartridges, small arms	1.4S
0014	Cartridges for weapons, blank *or* Cartridges, small arms, blank	1.4S
0015	Ammunition, smoke *with or without burster, expelling charge or propelling charge*	1.2G
0016	Ammunition, smoke *with or without burster, expelling charge or propelling charge*	1.3G

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0018	Ammunition, tear-producing *with burster, expelling charge or propelling charge*	1.2G
0019	Ammunition, tear-producing *with burster, expelling charge or propelling charge*	1.3G
0020*	Ammunition, toxic *with burster, expelling charge, or propelling charge*	1.2K
0021*	Ammunition, toxic *with burster, expelling charge, or propelling charge*	1.3K
0027	Black powder *or* Gunpowder, *granular or as a meal*	1.1D
0028	Black powder, compressed *or* Gunpowder, compressed *or* Black powder, in pellets *or* Gunpowder, in pellets	1.1D
0029	Detonators, nonelectric, *for blasting*	1.1B
0030	Detonators, electric, *for blasting*	1.1B
0033	Bombs, *with bursting charge*	1.1F
0034	Bombs, *with bursting charge*	1.1D
0035	Bombs, *with bursting charge*	1.2D
0037	Bombs, photo-flash	1.1F
0038	Bombs, photo-flash	1.1D
0039	Bombs, photo-flash	1.2G
0042	Boosters, *without detonator*	1.1D
0043	Bursters, *explosive*	1.1D
0044	Primers, cap type	1.4S
0048	Charges, demolition	1.1D
0049	Cartridges, flash	1.1G
0050	Cartridges, flash	1.3G
0054	Cartridges, signal	1.3G
0055	Cases, cartridge, empty with primer	1.4S
0056	Charges, depth	1.1D
0059	Charges, shaped, commercial, *without detonator*	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0060	Charges, supplementary explosive	1.1D
0065	Cord, detonating, *flexible*	1.1D
0066	Cord, igniter	1.4G
0070	Cutters, cable, explosive	1.4S
0072	Cyclotrimethylenetrinitramine, wetted *or* Cyclonite, wetted *or* Hexogen, wetted *or* RDX, wetted *with not less than 15 percent water by mass*	1.1D
0073	Detonators for ammunition	1.1B
0074	Diazodinitrophenol, wetted *with not less than 40 percent water or mixture of alcohol and water, by mass*	1.1A
0075	Diethyleneglycol dinitrate, desensitized *with not less than 25 percent nonvolatile water-insoluble phlegmatizer, by mass*	1.1D
0076	Dinitrophenol, *dry or wetted with less than 15 percent water, by mass*	1.1D
0077	Dinitrophenolates *alkali metals, dry or wetted with less than 15 percent water, by mass*	1.3C
0078	Dinitroresorcinol, *dry or wetted with less than 15 percent water, by mass*	1.1D
0079	Hexanitrodiphenylamine *or* Dipicrylamine *or* Hexyl	1.1D
0081	Explosive, blasting, type A	1.1D
0082	Explosive, blasting, type B	1.1D
0083	Explosive, blasting, type C	1.1D
0084	Explosive, blasting, type D	1.1D
0092	Flares, surface	1.3G
0093	Flares, aerial	1.3G
0094	Flash powder	1.1G
0099	Fracturing devices, explosive, *without detonators for oil wells*	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0101	Fuse, instantaneous, nondetonating *or* Quickmatch	1.3G
0102	Cord detonating *or* Fuse detonating *metal clad*	1.2D
0103	Fuse, igniter *tubular metal clad*	1.4G
0104	Cord, detonating, mild effect *or* Fuse, detonating, mild effect *metal clad*	1.4D
0105	Fuse, safety	1.4S
0106	Fuzes, detonating	1.1B
0107	Fuzes, detonating	1.2B
0110	Grenades, practice, *hand or rifle*	1.4S
0113	Guanyl nitrosaminoguanylidene hydrazine, wetted *with not less than 30 percent water, by mass*	1.1A
0114	Guanyl nitrosaminoguanyltetrazene, wetted *or* Tetrazene, wetted *with not less than 30 percent water or mixture of alcohol and water, by mass*	1.1A
0118	Hexolite, *or* Hexotol *dry or wetted with less than 15 percent water, by mass*	1.1D
0121	Igniters	1.1G
0124	Jet perforating guns, charged *oil well, without detonator*	1.1D
0129	Lead azide, wetted *with not less than 20 percent water or mixture of alcohol and water, by mass*	1.1A
0130	Lead styphnate, wetted *or* Lead trinitroresorcinate, wetted *with not less than 20 percent water or mixture of alcohol and water, by mass*	1.1A
0131	Lighters, fuse	1.4S
0132*	Deflagrating metal salts of aromatic nitroderivatives, n.o.s.	1.3C
0135	Mercury fulminate, wetted *with not less than 20 percent water, or mixture of alcohol and water, by mass*	1.1A
0136	Mines *with bursting charge*	1.1F
0137	Mines *with bursting charge*	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0138	Mines *with bursting charge*	1.2D
0143	Nitroglycerin, *desensitized with not less than 40 percent nonvolatile water insoluble phlegmatizer, by mass*	1.1D
0144	Nitroglycerin, solution in alcohol, *with more than 1 percent but not more than 10 percent nitroglycerin*	1.1D
0146	Nitrostarch, *dry or wetted with less than 20 percent water, by mass*	1.1D
0147	Nitro urea	1.1D
0150	Pentaerythrite tetranitrate, wetted *or* Pentaerythritol tetranitrate, wetted, *or* PETN, wetted *with not less than 25 percent water, by mass, or* Pentaerythrite tetranitrate, *or* Pentaerythritol tetranitrate, *or* PETN, desensitized *with not less than 15 percent phlegmatizer by mass*	1.1D
0151	Pentolite, *dry or wetted with less than 15 percent water, by mass*	1.1D
0153	Trinitroaniline *or* Picramide	1.1D
0154	Trinitrophenol *or* Picric acid, *dry or wetted with less than 30 percent water, by mass*	1.1D
0155	Trinitrochlorobenzene *or* Picryl chloride	1.1D
0158	Potassium salts of aromatic nitro-derivatives, *explosive*	1.3C
0159	Powder cake, wetted or Powder paste, wetted *with not less than 25 percent water, by mass*	1.3C
0160	Powder, smokeless	1.1C
0161	Powder, smokeless	1.3C
0167	Projectiles, *with bursting charge*	1.1F
0168	Projectiles, *with bursting charge*	1.1D
0169	Projectiles, *with bursting charge*	1.2D
0171	Ammunition, illuminating *with or without burster, expelling charge or propelling charge*	1.2G

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0173	Release devices, explosive	1.4S
0174	Rivets, explosive	1.4S
0180	Rockets, *with bursting charge*	1.1F
0181	Rockets, *with bursting charge*	1.1E
0182	Rockets, *with bursting charge*	1.2E
0183	Rockets, *with inert head*	1.3C
0186	Rocket motors	1.3C
0190*	Samples, explosive, *other than initiating explosives*	None Listed
0191	Signal devices, hand	1.4G
0192	Signals, railway track, explosive	1.1G
0193	Signals, railway track, explosive	1.4S
0194	Signals, distress, *ship*	1.1G
0195	Signals, distress, *ship*	1.3G
0196	Signals, smoke	1.1G
0197	Signals, smoke	1.4G
0203*	Sodium salts of aromatic nitro-derivatives, n.o.s. *explosive*	1.3C
0204	Sounding devices, explosive	1.2F
0207	Tetranitroaniline	1.1D
0208	Trinitrophenylmethylnitramine *or* Tetryl	1.1D
0209	Trinitrotoluene *or* TNT, *dry or wetted with less than 30 percent water, by mass*	1.1D
0212	Tracers for ammunition	1.3G
0213	Trinitroanisole	1.1D
0214	Trinitrobenzene, *dry or wetted with less than 30 percent water, by mass*	1.1D
0215	Trinitrobenzoic acid, *dry or wetted with less than 30 percent water, by mass*	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0216	Trinitro-meta-cresol	1.1D
0217	Trinitronaphthalene	1.1D
0218	Trinitrophenetole	1.1D
0219	Trinitroresorcinol *or* Styphnic acid, *dry or wetted with less than 20 percent water, or mixture of alcohol and water, by mass*	1.1D
0220	Urea nitrate, *dry or wetted with less than 20 percent water, by mass*	1.1D
0221	Warheads, torpedo *with bursting charge*	1.1D
0222	Ammonium nitrate, *with more than 0.2 percent combustible substances, including any organic substance calculated as carbon, to the exclusion of any other added substance*	1.1D
0224	Barium azide, *dry or wetted with less than 50 percent water, by mass*	1.1A
0225	Boosters with detonator	1.1B
0226	Cyclotetramethylenetetranitramine, wetted *or* HMX, wetted *or* Octogen, wetted *with not less than 15 percent water, by mass*	1.1D
0234	Sodium dinitro-o-cresolate, *dry or wetted with less than 15 percent water, by mass*	1.3C
0235	Sodium picramate, *dry or wetted with less than 20 percent water, by mass*	1.3C
0236	Zirconium picramate, *dry or wetted with less than 20 percent water, by mass*	1.3C
0237	Charges, shaped, flexible, linear	1.4D
0238	Rockets, line-throwing	1.2G
0240	Rockets, line-throwing	1.3G
0241	Explosive, blasting, type E	1.1D
0242	Charges, propelling, for cannon	1.3C
0243	Ammunition, incendiary, white phosphorus, *with burster, expelling charge or propelling charge*	1.2H
0244	Ammunition, incendiary, white phosphorus, *with burster, expelling charge or propelling charge*	1.3H

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0245	Ammunition, smoke, white phosphorus *with burster, expelling charge, or propelling charge*	1.2H
0246	Ammunition, smoke, white phosphorus *with burster, expelling charge, or propelling charge*	1.3H
0247	Ammunition, incendiary *liquid or gel, with burster, expelling charge or propelling charge*	1.3J
0248*	Contrivances, water-activated, *with burster, expelling charge or propelling charge*	1.2L
0249*	Contrivances, water-activated, *with burster, expelling charge or propelling charge*	1.3L
0250	Rocket motors with hypergolic liquids *with or without an expelling charge*	1.3L
0254	Ammunition, illuminating *with or without burster, expelling charge or propelling charge*	1.3G
0255	Detonators, electric, *for blasting*	1.4B
0257	Fuzes, detonating	1.4B
0266	Octolite or Octol, *dry or wetted with less than 15 percent water, by mass*	1.1D
0267	Detonators, nonelectric, *for blasting*	1.4B
0268	Boosters with detonator	1.2B
0271*	Charges, propelling	1.1C
0272*	Charges, propelling	1.3C
0275	Cartridges, power device	1.3C
0276	Cartridges, power device	1.4C
0277	Cartridges, oil well	1.3C
0278	Cartridges, oil well	1.4C
0279	Charges, propelling, for cannon	1.1C
0280	Rocket motors	1.1C
0281	Rocket motors	1.2C
0282	Nitroguanidine or Picrite, *dry or wetted with less than 20 percent water, by mass*	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0283	Boosters, *without detonator*	1.2D
0284	Grenades, *hand or rifle, with bursting charge*	1.1D
0285	Grenades, *hand or rifle, with bursting charge*	1.2D
0286	Warheads, rocket *with bursting charge*	1.1D
0287	Warheads, rocket *with bursting charge*	1.2D
0288	Charges, shaped, flexible, linear	1.1D
0289	Cord, detonating, *flexible*	1.4D
0290	Cord, detonating or Fuse, detonating *metal clad*	1.1D
0291	Bombs, *with bursting charge*	1.2F
0292	Grenades, *hand or rifle, with bursting charge*	1.1F
0293	Grenades, *hand or rifle, with bursting charge*	1.2F
0294	Mines *with bursting charge*	1.2F
0295	Rockets, *with bursting charge*	1.2F
0296	Sounding devices, explosive	1.1F
0297	Ammunition, illuminating *with or without burster, expelling charge or propelling charge*	1.4G
0299	Bombs, photo-flash	1.3G
0300	Ammunition, incendiary *with or without burster, expelling charge or propelling charge*	1.4G
0301	Ammunition, tear-producing *with burster, expelling charge or propelling charge*	1.4G
0303	Ammunition, smoke *with or without burster, expelling charge or propelling charge*	1.4G
0305	Flash powder	1.3G
0306	Tracers for ammunition	1.4G
0312	Cartridges, signal	1.4G
0313	Signals, smoke	1.2G
0314	Igniters	1.2G

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0315	Igniters	1.3G
0316	Fuzes, igniting	1.3G
0317	Fuzes, igniting	1.4G
0318	Grenades, practice, *hand or rifle*	1.3G
0319	Primers, tubular	1.3G
0320	Primers, tubular	1.4G
0321	Cartridges for weapons, *with bursting charge*	1.2E
0322	Rocket motors with hypergolic liquids *with or without an expelling charge*	1.2L
0323	Cartridges, power device	1.4S
0324	Projectiles, *with bursting charge*	1.2F
0325	Igniters	1.4G
0326	Cartridges for weapons, blank	1.1C
0327	Cartridges for weapons, blank *or* Cartridges, small arms, blank	1.3C
0328	Cartridges for weapons, inert projectile	1.2C
0329	Torpedoes *with bursting charge*	1.1E
0330	Torpedoes *with bursting charge*	1.1F
0331	Explosive, blasting, type B *or* Agent blasting, Type B	1.5D
0332	Explosive, blasting, type E *or* Agent blasting, Type E	1.5D
0333	Fireworks	1.1G
0334	Fireworks	1.2G
0335	Fireworks	1.3G
0336	Fireworks	1.4G
0337	Fireworks	1.4S
0338	Cartridges for weapons, blank *or* Cartridges, small arms, blank	1.4C

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0339	Cartridges for weapons, inert projectile *or* Cartridges, small arms	1.4C
0340	Nitrocellulose, *dry or wetted with less than 25 percent water (or alcohol), by mass*	1.1D
0341	Nitrocellulose, *unmodified or plasticized with less than 18 percent plasticizing substance, by mass*	1.1D
0342	Nitrocellulose, wetted *with not less than 25 percent alcohol, by mass*	1.3C
0343	Nitrocellulose, plasticized *with not less than 18 percent plasticizing substance, by mass*	1.3C
0344	Projectiles, *with bursting charge*	1.4D
0345	Projectiles, *inert with tracer*	1.4S
0346	Projectiles, *with burster or expelling charge*	1.2D
0347	Projectiles, *with burster or expelling charge*	1.4D
0348	Cartridges for weapons, *with bursting charge*	1.4F
0349*	Articles, explosive, n.o.s.	1.4S
0350*	Articles, explosive, n.o.s.	1.4B
0351*	Articles, explosive, n.o.s.	1.4C
0352*	Articles, explosive, n.o.s.	1.4D
0353*	Articles, explosive, n.o,s.	1.4G
0354*	Articles, explosive, n.o.s.	1.1L
0355*	Articles, explosive, n.o.s	1.2L
0356*	Articles, explosive, n.o.s.	1.3L
0357*	Substances, explosive, n.o.s.	1.1L
0358*	Substances, explosive, n.o.s.	1.2L
0359*	Substances, explosive, n.o.s.	1.3L
0360	Detonator assemblies, nonelectric, *for blasting*	1.1B
0361	Detonator assemblies, nonelectric, *for blasting*	1.4B
0362	Ammunition, practice	1.4G

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0363	Ammunition, proof	1.4G
0364	Detonators for ammunition	1.2B
0365	Detonators for ammunition	1.4B
0366	Detonators for ammunition	1.4S
0367	Fuzes, detonating	1.4S
0368	Fuzes, igniting	1.4S
0369	Warheads, rocket *with bursting charge*	1.1F
0370	Warheads, rocket *with burster or expelling charge*	1.4D
0371	Warheads, rocket *with burster or expelling charge*	1.4F
0372	Grenades, practice, *hand or rifle*	1.2G
0373	Signal devices, hand	1.4S
0374	Sounding devices, explosive	1.1D
0375	Sounding devices, explosive	1.2D
0376	Primers, tubular	1.4S
0377	Primers, cap type	1.1B
0378	Primers, cap type	1.4B
0379	Cases, cartridges, empty with primer	1.4C
0380	Articles, pyrophoric	1.2L
0381	Cartridges, power device	1.2C
0382*	Components, explosive train, n.o.s.	1.2B
0383*	Components, explosive train, n.o.s.	1.4B
0384*	Components, explosive train, n.o.s.	1.4S
0385	5-Nitrobenzotriazol	1.1D
0386	Trinitrobenzenesulforic acid	1.1D
0387	Trinitrofluorenone	1.1D
0388	Trinitrotoluene and Trinitrobenzene mixtures *or* TNT and trinitrobenzene mixtures *or* TNT and hexanitrostilbene mixtures *or* Trinitrotoluene and hexanitrostilbene mixtures	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0389	Trinitrotoluene mixtures containing Trinitrobenzene and Hexanitrostilbene *or* TNT mixtures containing trinitrobenzene and hexanitrostilbene	1.1D
0390	Tritonal	1.1D
0391	RDX and HMX mixtures, wetted *with not less than 15 percent water by mass or* RDX and HMX mixtures, desensitized *with not less than 10 percent phlegmatizer by mass*	1.1D
0392	Hexanitrostilbene	1.1D
0393	Hexotonal	1.1D
0394	Trinitroresorcinol, wetted or Styphnic acid, wetted *with not less than 20 percent water, or mixture of alcohol and water by mass*	1.1D
0395	Rocket motors, liquid fueled	1.2J
0396	Rocket motors, liquid fueled	1.3J
0397	Rockets, liquid fueled *with bursting charge*	1.1J
0398	Rockets, liquid fueled *with bursting charge*	1.2J
0399	Bombs with flammable liquid, *with bursting charge*	1.1J
0400	Bombs with flammable liquid, *with bursting charge*	1.2J
0401	Dipicryl sulfide, *dry or wetted with less than 10 percent water, by mass*	1.1D
0402	Ammonium perchlorate	1.1D
0403	Flares, aerial	1.4G
0404	Flares, aerial	1.4S
0405	Cartridges, signal	1.4S
0406	Dinitrosobenzene	1.3C
0407	Tetrazol-1-acetic acid	1.4C
0408	Fuzes, detonating, *with protective features*	1.1D
0409	Fuzes, detonating, *with protective features*	1.2D
0410	Fuzes, detonating, *with protective features*	1.4D
0411	Pentaerythrite tetranitrate *or* Pentaerythritol tetranitrate *or* PETN, *with not less than 7 percent wax by mass*	1.1D

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0412	Cartridges for weapons, *with bursting charge*	1.4E
0413	Cartridges for weapons, blank	1.2C
0414	Charges, propelling, for cannon	1.2C
0415*	Charges, propelling	1.2C
0417	Cartridges for weapons, inert projectile or Cartridges, small arms	1.3C
0418	Flares, surface	1.1G
0419	Flares, surface	1.2G
0420	Flares, aerial	1.1G
0421	Flares, aerial	1.2G
0424	Projectiles, *inert, with tracer*	1.3G
0425	Projectiles, *inert, with tracer*	1.4G
0426	Projectiles, *with burster or expelling charge*	1.2F
0427	Projectiles, *with burster or expelling charge*	1.4F
0428	Articles, pyrotechnic *for technical purposes*	1.1G
0429	Articles, pyrotechnic *for technical purposes*	1.2G
0430	Articles, pyrotechnic *for technical purposes*	1.3G
0431	Articles, pyrotechnic *for technical purposes*	1.4G
0432	Articles, pyrotechnic *for technical purposes*	1.4S
0433	Powder cake, wetted or Powder paste, wetted *with not less than 17 percent alcohol by mass*	1.1C
0434	Projectiles, *with burster or expelling charge*	1.2G
0435	Projectiles, *with burster or expelling charge*	1.4G
0436	Rockets, *with expelling charge*	1.2C
0437	Rockets, *with expelling charge*	1.3C
0438	Rockets, *with expelling charge*	1.4C
0439	Charges, shaped, commercial *without detonator*	1.2D
0440	Charges, shaped, commercial *without detonator*	1.4D
0441	Charges, shaped, commercial *without detonator*	1.4S

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0442	Charges, explosive, commercial *without detonator*	1.1D
0443	Charges, explosive, commercial *without detonator*	1.2D
0444	Charges, explosive, commercial *without detonator*	1.4D
0445	Charges, explosive, commercial *without detonator*	1.4S
0446	Cases, combustible, empty, without primer	1.4C
0447	Cases, combustible, empty, without primer	1.3C
0448	5-Mercaptotetrazol-1-acetic acid	1.4C
0449	Torpedoes, liquid fueled, with or without bursting charge	1.1J
0450	Torpedoes, liquid fueled, with inert head	1.3J
0451	Torpedoes with bursting charge	1.1D
0452	Grenades, practice, *hand or rifle*	1.4G
0453	Rockets, line-throwing	1.4G
0454	Igniters	1.4S
0455	Detonators, nonelectric *for blasting*	1.4S
0456	Detonators, electric *for blasting*	1.4S
0457	Charges, bursting, plastics bonded	1.1D
0458	Charges, bursting, plastics bonded	1.2D
0459	Charges, bursting, plastics bonded	1.4D
0460	Charges, bursting, plastics bonded	1.4S
0461*	Components, explosive train, n.o.s.	1.1B
0462*	Articles, explosive, n.o.s.	1.1C
0463*	Articles, explosive, n.o.s.	1.1D
0464*	Articles, explosive, n.o.s.	1.1E
0465*	Articles, explosive, n.o.s.	1.1F
0466*	Articles, explosive, n.o.s.	1.2C
0467*	Articles, explosive, n.o.s.	1.2D
0468*	Articles, explosive, n.o.s.	1.2E

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0469*	Articles, explosive, n.o.s.	1.2F
0470*	Articles, explosive, n.o.s.	1.3C
0471*	Articles, explosive, n.o.s.	1.4E
0472*	Articles, explosive, n.o.s.	1.4F
0473*	Substances, explosive, n.o.s.	1.1A
0474*	Substances, explosive, n.o.s.	1.1C
0475*	Substances, explosive, n.o.s.	1.1D
0476*	Substances, explosive, n.o.s.	1.1G
0477*	Substances, explosive, n.o.s.	1.3C
0478*	Substances, explosive, n.o.s.	1.3G
0479*	Substances, explosive, n.o.s.	1.4C
0480*	Substances, explosive, n.o.s.	1.4D
0481*	Substances, explosive, n.o.s.	1.4S
0482*	Substances, explosive, very insensitive, n.o.s., *or* Substances, EVI, n.o.s.	1.5D
0483	Cyclotrimethylenetrinitramine, desensitized *or* Cyclonite, desensitized *or* Hexogen, desensitized *or* RDX, desensitized	1.1D
0484	Cyclotetramethylenetetranitramine, desensitized *or* Octogen, desensitized *or* HMX, desensitized	1.1D
0485*	Substances, explosive, n.o.s.	1.4G
0486	Articles, explosive, extremely insensitive *or* Articles, EEI	1.6N
0487	Signals, smoke	1.3G
0488	Ammunition, practice	1.3G
0489	Dinitroglycoluril *or* Dingu	1.1D
0490	Nitrotriazolone *or* NTO	1.1D
0491*	Charges, propelling	1.4C
0492	Signals, railway track, explosive	1.3G

Table H-1. UNO HC 1 Requirements Data (Continued)

UNO Number	Proper Shipping Name	HC/DIV with SCG
0493	Signals, railway track, explosive	1.4G
0494	Jet perforating guns, charged, *oil well, without detonator*	1.4D
0495*	Propellant, liquid	1.3C
0496	Octonal	1.1D
0497*	Propellant, liquid	1.1C
0498*	Propellant, solid	1.1C
0499*	Propellant, solid	1.3C
* An asterisk appearing after the UN or NA Serial Number indicates that, unless otherwise excepted, the technical name of the hazardous material must be entered in parentheses on documentation and package marking in association with the basic description.		

H-2. Table H-2 below lists HC 1 NA identification numbers, PSNs, and HC/DIV with SCG. These PSNs are appropriate for describing materials for domestic transportation but may be inappropriate for international transportation under the provisions of international regulations (e.g., IMO, ICAO). An alternate PSN may be selected when either domestic or international transportation is involved. Table H-3 lists UN identification numbers, PSNs, and HC/DIV for Non-Hazard Class 1 entries.

Table H-2. NA HC 1 Requirements Data

NA ID Number	Proper Shipping Name	HC/DIV with SCG
0006	Explosive pest control devices	1.1E
0124	Jet perforating guns, charged oil well, with detonator	1.1D
0133	Mannitol hexanitrate, wetted or Nitromannite, wetted *with not less than 40 percent water, by mass or mixture of alcohol and water*	1.1A
0276	Model rocket motor	1.4C
0323	Model rocket motor	1.4S
0331	Ammonium nitrate-fuel oil mixture *containing only prilled ammonium nitrate and fuel oil*	1.5D
0337	Toy Caps	1.4S

Table H-2. NA HC 1 Requirements Data (Continued)

NA ID Number	Proper Shipping Name	HC/DIV with SCG
0349	Grenades, empty primed	1.4S
0350	Boosters with detonator	1.4B
0412	Explosive pest control devices	1.4E
0473	Barium styphnate *or* Lead mononitroresorcinate *or* Nitrosoguanidine	1.1A
0474*	Propellant explosive, liquid	1.1C
0477*	Propellant explosive, liquid	1.3C
0494	Jet perforating guns, charged oil well, with detonator	1.4D
* An asterisk appearing after the UN or NA Serial Number indicates that, unless otherwise excepted, the technical name of the hazardous material must be entered in parentheses on documentation and package marking in association with the basic description.		

Table H-3. UN Non-HC 1 Requirements Data

UN ID Number	Proper Shipping Name	HC/DIV
1325*	Flammable solids, organic, n.o.s.	4.1
1360	Calcium phosphide	4.3
1381	Phosphorus, white dry *or* Phosphorus, white, under water *or* Phosphorus, white, in solution *or* Phosphorus, yellow dry *or* Phosphorus, yellow, under water *or* Phosphorus, yellow, in solution	4.2
1693*	Tear gas substances, liquid, n.o.s. *or* Tear gas substances, solid, n.o.s.	6.1
1697	Chloroacetophenone (CN), *solid or liquid*	6.1
1993*	Flammable liquids, n.o.s.	3.
2016*	Ammunition, toxic, nonexplosive, *without burster or expelling charge, nonfuzed*	6.1

Table H-3. UN Non-HC 1 Requirements Data (Continued)

UN ID Number	Proper Shipping Name	HC/DIV
2017	Ammunition, tear-producing, nonexplosive, *without burster or expelling charge, nonfuzed*	6.1
2805	Lithium hydride, fused solid	4.3
* An asterisk appearing after the UN or NA Serial Number indicates that, unless otherwise excepted, the technical name of the hazardous material must be entered in parentheses on documentation and package marking in association with the basic description.		

Glossary

ABL	ammunition basic load
ABLCS	Ammunition Basic Load Computation System
AC	Active Component
AC	hydrogencyanide (blood agent)
ACC	ammunition condition code
AD	air-droppable
ADACS	Automatic Data Collection System
ADAM	air defense antimissile
AGM	air-to-ground missile
AINS	ammunition information notices
AIT	automatic information technology
AJI	antijamming improvements
AMCOM	(US Army) Aviation and Missile Command
AMSTAT	ammunition status report
AO	area of operations
AP	armor piercing
APDS-T	armor-piercing, discarding sabot-tracer
APE	ammunition peculiar equipment
APERS	antipersonnel
APFSDS-T	armor-piercing, fin-stabilized, discarding sabot-tracer
API	armor-piercing incendiary
APOD	aerial port of debarkation
AR	Army regulation
ARDEC	Armament Research, Development and Engineering Center
ARNG	Army National Guard
ARTEP	Army Training and Evaluation Program
ASA	ammunition support activity
ASCC	Army service component commander
ASIS	Ammunition Surveillance Information System
ASL	authorized stockage list
ASP	ammunition supply point
AST	ammunition support team

AT	antitank
ATACMS	Army Tactical Missile System
atck	attack
ATP	ammunition transfer point
ATR	Ammunition Transfer Record (DA Form 4508)
BAO	brigade ammunition office
BCLST	bar code laser scanner terminal(s)
BCM	binary chemical munitions
BCT	brigade combat team
BGM	basic guided missile
BIDS	Biological Identification Detection System
BII	basic issue item(s)
BLAHA	basic load ammunition holding area
BLSA	basic load storage area
BLSTG	blasting
BOE	Bureau of Explosives
BOIP	basis of issue plan
BSA	brigade/battalion support area
C&P	component and packaging
C2	command and control
C3I	command, control, communications, and intelligence
cal	caliber
CARC	chemical agent-resistant coating
CB	chemical, biological
CBU	cluster bomb unit
CCSS	Commodity Command Standard System
CDT	cargo documentation team
CEA	captured enemy ammunition
CEE	captured enemy equipment
CEM	captured enemy materiel
centigray	A unit of absorbed dose of radiation (one centigray equals one rad).
CFR	Code of Federal Regulations

cGy	centigray
CHE	cargo/container handling equipment
chem	chemical
CIIC	controlled inventory item code
CINC	commander in chief
CLASS III	(supply) petroleum, oil, and lubricants
CLASS V	(supply) ammunition
CLGP	cannon-launched guided projectile (Copperhead)
CLSTR	cluster
CMCC	corps movement control center
CMEC	captured materiel exploitation center
CMMC	corps materiel management center
CN	A chemical agent (tear gas).
cntr	container
CO	commander/commanding officer
COMMZ	communications zone
COMP	composition
COMTECHREP	complementary technical report
CONUS	Continental United States
CONUSA	Continental United States Army
COSCOM	corps support command
COTS	commercial off-the-shelf
CP	command post
CS	combat service
CS	chlorobenzalmalononitrile (chemical agent, tear gas)
CSA	corps storage area
CSB	corps support battalion
CSG	corps support group
CSR	controlled supply rate
CSS	combat service support
CSSCS	Combat Service Support Control System
CTA	common table of allowances
ctg	cartridge
ctn	carton

CTT	common task test
DA	Department of the Army
DAAS	Defense Automated Address System
DAC	Defense Ammunition Center (formerly USADACS); also Department of the Army civilian
DAMMS-R	Department of the Army Movement Management System-Redesigned
DAO	division ammunition office(r)
DARCOM	(US Army) Development and Readiness Command
DAS-3	Decentralized Automated Service Support System-3
DCS	Defense Communications System
DDESB	Department of Defense Explosives Safety Board
DED	detailed equipment decontamination
demo	demolition
DETECHREP	detailed technical report
DISCOM	division support command
div	division
DIVARTY	division artillery
DLA	Defense Logistics Agency
DMMC	division materiel management center
DMWR	depot maintenance work requirement
DOD	Department of Defense
DODAAC	Department of Defense activity address code
DODAC	Department of Defense ammunition code
DODIC	Department of Defense identification code
DOD STD	Department of Defense standard
DOL	director of logistics
DOS	days of supply
DOT	Department of Transportation
DP	dual purpose
DS	direct support
DSA	division support area
DSR	depot surveillance record
DTD	detailed troop decontamination

DTO	division transportation office(r)
DTR	daily transaction report
DWG	drawing
EAC	echelon above corps
ECCM	electronic counter-countermeasures
ECM	electronic countermeasures
ECP-S	engineering change proposal-software
ED	emergency destruction
e.g.	for example
EID	explosive initiating device
EMP	electromagnetic pulse
EOD	explosive ordnance disposal
ETA	estimated time of arrival
FAE	fuel-air explosive
F/AP	fragmentary/armor-piercing
FARP	forward arming and refueling point
FEDLOG	Federal Logistics Record
FLOT	forward line of own troops
FM	field manual
FMIG	Foreign Materiel Intelligence Group
FMTV	Family of Medium Tactical Vehicles
FORSCOM	(US Army) Forces Command
frag	fragment/fragmentary
FSB	forward support battalion
FSC	field storage category
FSC	Federal Supply Classification
FSCG	Federal Supply Classification Group
FSTC	US Army Foreign Science and Technology Center
FSU	field storage unit
FTX	field training exercise
FY	fiscal year
G2	division security/intelligence staff
G3	division operations staff
G4	division logistics staff

GB	chemical nerve agent, Sarin
GCSS-Army	Global Combat Support System-Army
GM	guided missile
GMLR	guided missile and large rocket
GREN	grenade
grnd	ground
GS	general support
GSA	General Services Administration
GTA	graphic training aid
HC	aluminum zinc oxide hexachloroethane (chemical smoke)
HC	hazard class
HC/D	hazard class/division
HE	high explosive(s)
HEAT	high explosive antitank
HEDP	high explosive, dual purpose
HEI	high explosive incendiary
HEI-T	high explosive incendiary-tracer
HEMTT	heavy expanded mobility tactical truck
HEP	high explosive plastic
HEP-T	high explosive plastic-tracer
HHC	headquarters and headquarters company
HHD	headquarters and headquarters detachment
HLP	heavy lift platoon
HN	host nation
HNS	host nation support
HQDA	Headquarters, Department of the Army
hzd	hazard
IAEA	International Atomic Energy Agency
IATA	International Air Transportation Association
IAW	in accordance with
IBD	inhabited building distance
IBM	International Business Machines
ICAO	International Civil Aviation Organization
ICM	improved conventional munitions

ICS3	Integrated Combat Service Support System
i.e.	that is
Illum	illuminating
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Association
incd	incendiary
INSCOM	(US Army) Intelligence and Security Command
IPE	individual protective equipment
IR	infared
ISB	intermediate staging base
ISO	International Standardization Organization
ITV	in-transit visibility
J2	joint staff (intelligence)
J3	joint staff (operations)
J4	joint staff (logistics)
JATO	jet-assisted takeoff
JCMEC	Joint Captured Materiel Exploitation Center
JHCS	Joint Hazard Classification System
JIC	Joint Intelligence Center
LAN	local area network
LAP	link access procedure/process
LAPES	low altitude parachute extraction system
lb	pound
lkd	linked
LMTV	light medium tactical vehicle
lnchr	launcher
LOC	lines of communication
LOGPLAN	logistics plan
LOGSA	logistics support activity
LSE	logistics support element
MACOM	major command
MATO	materiel and transportation office(r)
MCA	movement control agency
MCB	movement control battalion

MCC	movement control center
MCL	mission configured load
MCO	movement control officer
MCT	movement control team
METL	mission essential task list
METT-TC	mission, enemy, terrain, troops, time available, and contractors on the battlefield
MHE	materials handling equipment
MI	military intelligence
MICLIC	mine clearing line charge
MILHBK	military handbook
MILSTAMP	Military Standard Transportation and Movement Procedures
MIL-STD	military standard
MILSTRIP	Military Standard Requisitioning and Issue Procedures
MLP	medium lift platoon
MLRS	Multiple Launch Rocket System
mm	millimeter
MMC	materiel management center
MMR	Military Munitions Rule
MOADS	Maneuver Oriented Ammunition Distribution System
MOADS-PLS	Maneuver Oriented Ammunition Distribution System Palletized Load System
mod	modified
MOPP	mission oriented protective posture
MOPP-4	mission oriented protective posture-4
MOS	military occupational specialty
MP	military police
MPSM	multipurpose submunition
MRCT	movement regulating control team
MRO	materiel release order
MSB	main support battalion

MSR	main supply route
MT	megaton
mtl	metal
MTMC	Military Traffic Management Command
MTOE	modified table(s) of organization and equipment
MTSQ	mechanical time, super quick (fuze)
NA	North America
NBC	nuclear, biological, chemical
NCO	noncommissioned officer
NCOIC	noncommissioned officer in charge
NDI	nondevelopmental item
NEQ	net explosive quantity
NEW	net explosive weight
NFPA	National Fire Protection Association
NGB	National Guard Bureau
NICP	National Inventory Control Point
NIIN	national item identification number
NSN	national stock number
OCONUS	outside continental United States
OD	olive drab
OPLAN	operations plan
OPLOG	operations logistics
OPORD	operations order
OPSEC	operations security
OSC	Operations Support Command (Comprised of former AMCCOM and IOC
OSHA	Occupational Safety and Health Agency
pam	pamphlet
para	parachute
PC	personal computer
PD	point detonating
pers	personnel
PETN	pentaerythrite tetranitrate (explosive)
pk	package

PLL	prescribed load list
PLS	palletized load system
POC	point of contact
POD	port of debarkation
POE	port of embarkation
POL	petroleum, oil, and lubricants
POW	prisoner of war
PPE	personal protective equipment
prac	practice
PRETECHREP	preliminary technical report
proj	projectile
PSN	proper shipping name
PWP	plasticized white phosphorus
QA	quality assurance
QA/QC	quality assurance/quality control
QANET	quality assurance network
QASAS	quality assurance specialist(s) (ammunition surveillance)
Q-D	quantity-distance
QRF	quick reaction force
qty	quantity
RAAM	remote antiarmor mine (munition)
RAOC	rear area operations center
RAP	rear area protection
RASA	ready ammunition storage area
RB	rubidium
rd(s)	round(s)
RDX	rapid detonating explosive (cyclotrimethylenetrinitramine)
REPSHIP	report of shipment
RF	radio frequency
RIC	routing identifier code
rkt(s)	rocket(s)
RMP	reprogrammable microprocessor
ROD	report of discrepancy
RSO&I	reception, staging, onward movement, and integration

RSP	render safe procedure
RSR	required supply rate
RTCH	rough terrain container handler
S&P	stake and platform
S&T	supply and transportation
S&TI	scientific and technical intelligence
S2	battalion or brigade level security/intelligence staff
S3	battalion or brigade level operations staff
S4	battalion or brigade level logistics staff
SAAS	Standard Army Ammunition System
SAAS-DAO	Standard Army Ammunition System-Division Ammunition Office
SAAS-MOD	Standard Army Ammunition System-Modernization
SALUTE	size, activity, location, unit, time, and equipment
SAM	system administrator manual
SASO	stability and support operations
SB	supply bulletin
SCG	storage compatibility group
SCL	strategic configured load
scrng	screening
ser	series
SF	special form
SIDPERS	Standard Installation/Division Personnel System
simul	simulated/simulation
SITREP	situation report
SM	soldiers' manual
SME	subject matter expert
smk	smoke
SOFA	status of forces agreement(s)
SOP	standing operating procedure
SOUMS	safety of use messages
SPBS-R	Standard Property Book System-Redesign
SPOD	sea port of debarkation
SSA	supply support activity

ST	short ton(s)
STAMIS	Standard Army Management Information System
STANAG	standardization agreement
STRAC	Standards in Training Commission
STRAP	system training plan
surf	surface
TAACOM	theater army area command
tac	tactical
TACCS	Tactical Army Combat Service Support Computer System
TAFR	Training Ammunition Forecast Report
TAMIS-R	Training Ammunition Management Information System-Redesigned
TAMMC	theater army materiel management center
TAT	to accompany troops
TAV	total asset visibility
TB	technical bulletin
TC	training circular
TC-AIMS-II	Transportation Coordinators Automated Information for Movement System-II
TCF	tactical combat force
TCMD	transportation control movement document
TCN	transportation control number
TEA	triethyl aluminum
TECHINT	technical intelligence
TEU	technical escort unit
T-LKD	tracer-linked
TM	technical manual
TMR	transportation movement release
TMT	transportation motor transport
TNT	trinitrotoluene (dynamite)
TO	theater of operations
TOE	table(s) of organization and equipment
TOW	tube-launched, optically-tracked wire-guided missile system
TP	target practice

TPCSDS-T	target practice cone-stabilized discarding sabot-tracer (ammunition)
TP-T	target practice-tracer (ammunition)
TRADOC	(United States Army) Training and Doctrine Command
TSA	theater storage area
TSC	theater support command
TTP	trailer transfer point
UIC	unit identification code
UK	United Kingdom
ULLS-S4	Unit Level Logistics System, S4 Module
UNO	United Nations Organization
UPS	uninterruptible power system/supply
US	United States
USA	United States Army
USAEHA	United States Army Environmental Hygiene Agency
USAF	United States Air Force
USAIA	United States Army Intelligence Agency
USAMC	United States Army Materiel Command
USAR	United States Army Reserve
USCG	United States Coast Guard
UXO	unexploded ordnance
VT	variable time
VTAADS	Vertical Army Authorization Document System
WARS	Worldwide Ammunition Reporting System
whd	warhead
WHNS	wartime host nation support
wht	white
WMD	weapons of mass destruction
wnd	wooden
WP	white phosphorus
wt	weight
XO	executive officer

Bibliography

AMC 19-48-75-5 (Drawing Index). http://www.dac.army.mil/det/dapam/toc.html. 29 January 1999.

Ammunition Book Complete ON-LINE. https://www4.ioc.army.mil/sm/drill.htm.

AR 5-13. *Training Ammunition Management System*. 20 December 1994.

AR 50-6. *Nuclear and Chemical Weapons and Materiel, Chemical Surety*. 1 February 1995.

AR 55-38. *Reporting of Transportation Discrepancies in Shipments*. 31 August 1992.

AR 75-1. *Malfunctions Involving Ammunition and Explosives*. 20 August 1993.

AR 95-27. *Operational Procedures for Aircraft Carrying Hazardous Materials.* 11 November 1994.

AR 190-11. *Physical Security of Arms, Ammunition and Explosives.* 30 September 1993.

AR 190-14. *Carrying of Firearms and Use of Force for Law Enforcement and Security Duties*. 12 March 1993.

AR 190-59. *Chemical Agent Security Program*. 27 June 1994.

AR 220-10. *Preparation for Oversea Movement of Units (POM*). 15 June 1973.

AR 380-67. *The Department of the Army Personnel Security Program*. 9 September 1988.

AR 381-26. *Army Foreign Materiel Exploitation Program*. 27 May 1991.

AR 385-10. *The Army Safety Program*. 23 May 1988.

AR 385-40. *Accident Reporting and Records.* 1 November 1994.

AR 385-64. *U.S. Army Explosives Safety Program*. 28 November 1997.

AR 420-90. *Fire and Emergency Services.* 10 September 1997.

AR 702-6. *Ammunition Stockpile Reliability Program (ASRP) and Army Nuclear Weapons Stockpile Reliability Program (ANWSRP).* 30 July 1993.

AR 710-2. *Inventory Management Supply Policy Below the Wholesale Level.* 31 October 1997.

AR 735-5. *Policies and Procedures for Property Accountability*. 31 January 1998.

AR 735-11-2. *Reporting of Item and Packaging Discrepancies.* 6 December 1991.

AR 740-1. *Storage and Supply Activity Operations.* 23 April 1971.

Code of Federal Regulations, Title 49 (49CFR), Transportation. www.access.gpo.gov/nara/cfr/cfr-table-search.html. 1 October 1999.

Conventional Ammunition Substitutability Interchangeability List. AMCCOM.

DA Form 581. *Request For Issue and Turn-in of Ammunition.* July 1999.

DA Form 581-1. *Request for Issue and Turn-in of Ammunition (Continuation Sheet).* July 1999.

DA Form 984. Munition Surveillance Report—Descriptive Data of Ammunition Represented by Sample. June 1980.

DA Form 1687. *Notice of Delegation of Authority–Receipt for Supplies.* January 1982.

DA Form 2028. *Recommended Changes to Publications and Blank Forms.* 1 February 1974.

DA Form 2064. *Document Register for Supply Actions.* January 1982.

DA Form 2415. *Ammunition Condition Report.* 1 December 1977.

DA Form 3020-R. *Magazine Data Card*. August 1989.

DA Form 3022-R. *Army Depot Surveillance Record*. May 1990.

DA Form 3023. *Gage Record*. 1 July 1965.

DA Form 3151-R. *Ammunition Stores Slip*. April 1976.

DA Form 3782. *Suspended Notice.* September 1971.

DA Form 4508. *Ammunition Transfer Record*. May 1976.

DA Form 5203. *DODIC Master/Lot Locator Record*. May 1983.

DA Form 5204. *Serial Number Record*. May 1983.

DA Form 5514-R. *TAMIS Training Ammunition Forecast Report.* April 1986.

DA Form 5515. *Training Ammunition Control Document*. August 1989.

DA Form 5515-1. *Training Ammunition Control Document (Continuation Sheet).* August 1989.

DA Pam 350-38. *Standards in Weapons Training*. 3 July 1997.

DA Pam 385-1. *Small Unit Safety Officer/NCO Guide*. 22 September 1993.

DA Pam 385-64. *Ammunition and Explosives Safety Standards.* 28 November 1997.

DA Pam 710-2-1. *Using Unit Supply System (Manual Procedures).* 31 December 1997.

DA Pam 710-2-2. *Supply Support Activity Supply System: Manual Procedures.* 30 September 1998.

DA Pam 738-750. *Functional Users Manual for the Army Maintenance Management System (TAMMS).* 1 August 1994.

DD Form 250. *Materiel Inspection and Receiving Report.* November 1992.

DD Form 626. *Motor Vehicle Inspection (Transporting Hazardous Materials).* October 1995.

DD Form 836. *Shipping Paper and Emergency Response Information for Hazardous Materials Transported by Government Vehicles.* July 1996.

DD Form 1348-1A. *Issue Release/Receipt Document.* July 1991.

DD Form 1384. *Transportation Control and Movement Document*. 1 April 1966.

DD Form 1387-2. S*pecial Handling Data/Certification*. June 1986.

DD Form 1575. *Suspended Tag-Materiel*. October 1966.

DD Form 1575-1. *Suspended Label-Materiel*. 1 October 1966.

DD Form 1650. *Ammunition Data Card*. September 1986.

DD Form 1911. *Materiel Courier Receipt*. May 1982.

DOD Regulation 4500.9-R. *Defense Transportation Regulation*. Part I, *Passenger Movement*. August 1995. Part II, *Cargo Movement*. April 1996. Part III, *Mobility*. April 1997. Part IV, *Personal Property*. August 1999.

DO49 Technical Report DPG/TA-88/030. *Decontamination of Selected Military Equipment: US Army Ammunition Stocks*. September 1988.

FM 3-3. *Chemical and Biological Contamination Avoidance*. 16 November 1992.

FM 3-3-1. *Nuclear Contamination Avoidance*. 9 September 1994.

FM 3-4. *NBC Protection*. 29 May 1992.

FM 3-4-1. *Fixed Site Protection*. 16 August 1989.

FM 3-5. *NBC Decontamination*. 17 November 1993.

FM 3-7. *NBC Field Handbook*. 29 September 1994.

FM 3-100. *Chemical Operations Principles and Fundamentals*. 8 May 1996.

FM 5-250. *Explosives and Demolitions*. 30 July 1998.

FM 9-6. *Munitions Support in the Theater of Operations*. 20 March 1998.

FM 9-15. *Explosive Ordnance Disposal Service and Unit Operations*. 8 May 1996.

FM 9-20. *Technical Escort Operations*. 3 November 1997.

FM 10-67-1. *Concepts and Equipment of Petroleum Operations*. 2 April 1998.

FM 10-450-3. *Multiservice Helicopter Sling Load: Basic Operations and Equipment*. 10 April 1997.

FM 19-30. *Physical Security*. 1 March 1979.

FM 20-3. *Camouflage*. 14 November 1990.

FM 21-16. *Unexploded Ordnance (UXO) Procedures*. 30 August 1994.

FM 34-54. *Technical Intelligence*. 30 January 1998.

FM 55-10. *Movement Control*. 9 February 1999.

FM 55-60. *Army Terminal Operations*. 15 April 1996.

FM 55-80. *Army Container Operations*. 13 August 1997.

FM 63-2. *Division Support Command, Armored, Infantry, and Mechanized Infantry Divisions*. 20 May 1991.

FM 63-2-1. *Division Support Command Light Infantry, Airborne, and Air Assault Divisions*. 16 November 1992.

FM 71-100. *Division Operations*. 28 August 1996.

FM 100-15. *Corps Operations*. 29 October 1996.

FORSCOM Directive 525-5. *Alert Force Requirements and Response Standards (U)*. 1 August 1992.

FORSCOM Regulation 700-3. *Ammunition Basic Load*. 31 March 1993.

FORSCOM Regulation 700-4. *Ammunition*. 1 October 1990.

Hazard Classification of United States Military Explosives and Munitions (Little Yellow Book) On-Line. www.dac.army.mil/AV/YELLOW_BOOK.HTM. Revision 10, October 1997.

Joint Hazard Classification System (JHCS) on the Web. www.dac.army.mil/es/est/hc.asp.

NFPA 70. *National Electrical Code*. 1999.

SB 38-26. *Nonnuclear Ammunition Supply Rates (U)*. 20 April 1979.

SB 742-1. *Inspection of Supplies and Equipment Ammunition Surveillance Procedures*. 1 June 1998.

SF 361. *Transportation Discrepancy Report*. March 1984.

SF 364. *Report of Discrepancy (ROD)*. February 1980.

Standard Army Ammunition System-Modernization End User's Manual and Systems Administrator Handbook NT 4.0. http://www.gcss-army.lee.army.mil/saashdbk/default.htm. 20 January 1999.

TB 9-1300-278. *Guidelines for Safe Response to Handling, Storage, and Transportation Accidents Involving Army Tank Munitions or Armor Which Contain Depleted Uranium*. 21 July 1996.

TB 9-1300-385. *Munitions Restricted or Suspended*. 1 January 1999.

TB 43-0142. *Safety Inspection and Testing of Lifting Devices*. 28 February 1997.

TB MED-502. *Occupational and Environmental Health Respiratory Protection Program*. 15 February 1982.

TC 3-4-1. *Chemical Agent Monitor Employment*. 17 December 1991.

TM 9-1300-200. *Ammunition, General*. 3 October 1969.

TM 9-1300-250. *Ammunition Maintenance*. 25 September 1969.

TM 9-1375-200/2. *Use of Mine, Anittank: HE, Heavy, M15, as a Substitute for Charge Assembly Demolition: M37 or M183*. 14 June 1971.

TM 9-1375-213-12. *Operator's and Unit Maintenance Manual: Demolition Materials*. 30 March 1973.

TM 38-250. *Preparing Hazardous Materials for Military Air Shipments*. 1 March 1997.

TM 43-0001-47. *Army Equipment Data Sheets, Ammunition Peculiar Equipment (APE)*. 22 December 1993.

TRADOC Pamphlet 525-20. *US Army Operational Concept for Individual and Collective Measures for Chemical, Biological, and Radiological (CBR) Defense*. 30 July 1982.

USAEHA Technical Guide No. 146. *Pentachlorophenol-Treated Materials*. September 1991.

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The measure of chemical stability and the prediction of safe storage life is of prime interest to the manufacturer and user of propellants. This report will discuss the results obtained with standard artillery propellant when exposed to artificial ageing at various temperatures. The measurements of residual stabilizer versus time have been used as the criteria for propellant deterioration. A kinetic interpretation of this deterioration phenomena employing Berthelot's Law demonstrates that a family of straight lines can be plotted characterizing the length of time necessary at the various test temperatures to obtain a given variation of stabilizer content. By establishing realistic cut-off points in regard to stabilizer content, propellant safe life may be safely calculated at any storage temperature.

OBJECT

To apply standard analytical methods to propellant stabilizer determination in order to establish the rate of loss of stabilizer during periods of high temperature propellant ageing, applying Berthelot's Law of deterioration phenomena to the resulting data in an effort to predict propellant chemical safe life at any storage temperature.

SUMMARY

As part of a project entitled "Long Range Study of Prediction of Safe Life of Propellants", benefits which may be derived by the application of testing procedures or concepts are reviewed and evaluated to determine their relevance. To this end, the testing technique described in this report and the kinetic interpretation of the resulting test data have shown much promise as a method of forecasting propellant chemical safe life on small samplings of standard single-, double- and triple-base U. S. Army artillery propellant formulations. However, work must be expanded to make a more comprehensive review of propellants of U. S. Army interest and to study and refine the approach so that full application of this testing routine can be included in the propellant surveillance effort.

INTRODUCTION

One of the major problems concerned with the manufacture and use of propellants is the measurement of their chemical stability and the prediction of their safe storage life. The U. S. Army has substantial quantities of artillery propellants in storage. These various artillery propellants are subject to degradation with ageing, the end result being spontaneous ignition. Therefore, it is mandatory that a continuous knowledge of the stability status of this stock be acquired. The Propellants Division, Picatinny Arsenal, has the responsibility for this mission, and currently maintains control over these stocks by conducting the 65.5°C. Surveillance Test and the propellant stock activity described in references (1) and (2) respectively. These two programs involve all lots of artillery propellant manufactured for the U. S. Army.

The 65.5°C. Surveillance Test depends upon an end-point which is defined as the appearance of visible red fumes of nitrogen dioxide over the propellant sample stored at 65.5°C. It has been established through years of experience that the development of the end-point in 20 days or less denotes a storage hazard of the ambient stored stock but with an ample safety margin for disposition action on any remnant of that lot of propellant.

The propellant stock program has only very recently been implemented, the scope of this activity now relating to propelling charges and/or bulk propellant actually on hand in Field Service and Industrial Stock installations. Stabilizer content determinations of representative samples of each lot forwarded to this installation from the storage facilities form the basis for safe life determinations of this active stock. From the data developed by this program, in addition to those results observed in the 65.5°C. Surveillance Test, a sound, comprehensive stability control of all U. S. Army propellant stock is accomplished.

The benefits derived from such programs far outweigh the costs of testing, in that these measurements are the controlling factor in preventing loss of property and possibly life. The results of these programs can be translated into money, material and manhour savings by insuring the use of only acceptable propellant in loading and reblending operations, and by reducing storage costs through the disposal of unserviceable propellants. Additionally, a technical advantage is realized from conducting the 65.5°C. Surveillance Test in that opportunity is provided to perform related studies concerned with the safe life properties of propellants.

It is widely recognized in the study of propellant chemical deterioration that the measurement of residual stabilizer content offers the best means of establishing the stability potential of these materials. The method of analysis is, of course, of the greatest importance. It must be analytically sound, reproducible, relatively simple and capable of providing results which can be meaningfully interpreted. In the last few years, such a method was developed and is presently replacing some of the older wet chemical methods whose results were questionable when applied to aged propellants. This method is described in detail in Reference 3. The available propellant stabilizer is separated from hot alkali by steam distillation and analyzed spectrophotometrically. For this, the distillate is diluted to a standard volume with ethanol and the absorbance of the solution measured at 285 and or 247 mμ for the determination of available stabilizer as diphenylamine or ethyl centralite respectively. This method of analysis is employed to accomplish the surveillance activity described in Reference 2.

Recently the NATO countries were in need of an evaluation procedure that would assure acceptor countries that propellants received from others would have a proven chemical stability for a given period of time when stored at ambient conditions. After many stability tests were reviewed and evaluated through the conduct of round robins to insure that strict analytical agreement could be realized among world-wide participating laboratories, the above mentioned method for the determination of available stabilizer content was accepted, with the establishment of suitable cut-off points. It was assumed that if a propellant withstood a heating period of 60 days at 65.5°C., without undue depletion of available stabilizer content, then that propellant would have a proven chemical stability for 5 years storage at ambient conditions.

Once it was demonstrated that a reliable method of analysis had been established, capable of predicting the safe life of propellants for a five year period, it was of interest to attempt to apply this technique to predict the safe life of propellants for a much longer time. It was felt that by the establishment of realistic cut-off points in regard to stabilizer content, it should be possible to calculate safe life of propellant at any storage temperature with some degree of accuracy and with an ample margin of safety.

In March 1964, the French delegation at one NATO meeting suggested that kinetic interpretation of decomposing propellant could be interpreted by the use of Berthelot's Law of deterioration phenomena (References 4 and 5). With these tools and funds made available under project title, "Long Range Study of Prediction of Safe Life of Propellants", this study was initiated.

RESULTS

The formulations of the propellants studied under this program are tabulated in Table 2. In order to verify the agreement between the experimental results developed by the application of Berthelot's Law and the actual decomposition occurring under normal storage conditions, data representing propellants of different ages are presented in Table 3.

For each temperature investigated, curves were plotted showing the variation of the stabilizer content with time (plotting the stabilizer content along the ordinate and the time along the abscissa) thus representing these two variables in linear coordinates. These curves are shown in Figures 1 and 2 representing single-base M6 formulation, Figures 3 and 4 representing double-base M9 formulation, Figures 5 and 6 representing triple-base M30 formulation and Figures 7 and 8 representing single-base M10 formulation.

The graphical expressions applying Berthelot's Law to the developed data for M6, M9, M30 and M10 propellant formulations are shown in Figures 9, 10, 11 and 12 respectively.

Figure 13 shows data comparing Arrhenius' vs. Berthelot's equations.

DISCUSSION

Characteristics of the formulations under study, the compositions of which are shown in Table 2, are generally that single- and triple-base propellants will resist deterioration at high temperature exposure better than double-base propellant formulations. Conditioning temperatures for this study were, therefore, chosen at 10°C. intervals between 60° and 100°C. for single- and triple-base propellants, and between 60° and 90°C. for double-base propellants. These conditions are considered realistic for the three types of propellants considered. The behavior of the compositions heated at these different temperatures was determined by means of stabilizer analysis performed at specific time intervals in order to obtain a basis for extrapolation to lower storage temperatures. Therefore, through artificial ageing of the propellants at various temperatures and measuring the residual stabilizer content spectrophotometrically as described in Reference 3, the deterioration rate curves shown in Figures 1 through 8 were developed. In general the shapes of these curves are quite similar and display a rapid and relatively linear depletion rate up to approximately 70% of the overall deterioration pattern. As ageing progresses the curves exhibit a point of inflection and then proceed very slowly to approach 100% dissipation of the stabilizer. This apparent change of reaction rate can no doubt be attributed to the relatively high concentrations of the deterioration products of the stabilizer at this stage which themselves are capable of stabilization. Conditioning and stabilizer analysis were halted when the stabilizer level reached 0.1%, since it was found that at this point the propellant at these high temperatures was approaching hazard. It is likely that the reaction mechanisms are influenced by temperature and that the results of many high temperature tests are not reliable for safe life studies. However, since reaction mechanisms and rates decrease at lower storage temperatures, extrapolations derived from this high temperature work leave an ample margin of safety for disposition action of potentially hazardous propellants.

The points of interest on these graphs are the intersections of the lines corresponding to the consumption of 10, 20, 30, 40 and 50% of the stabilizer with the deterioration rate curves for each storage temperature. For convenience sake, alpha (α_X) defines the length of time (measured in days) necessary for obtaining a decrease of X% of the stabilizer content. Such values may be used for kinetic interpretation employing Berthelot's Law of the deterioration phenomena.

Berthelot's Law is applied to develop curves reflecting the variation of the rate of reaction with temperature. It is written as follows:

$$\log K = aT + b \qquad (1)$$

where T is the reaction temperature in degrees Kelvin, a and b are coefficients characteristic of the product under study; K is the rate constant at temperature T.

Constant K can be calculated only when the mechanism of the reaction, and especially the latter's order, is known; this is not the case in the thermal decomposition of propellants. When K cannot be determined, it is possible to replace it with time t, which is inversely proportional to K.

$$K = c/t \qquad (2)$$

where t is the time necessary to obtain a given variation of a constituent, and c is the concentration of that constituent (for example a 50% decrease in stabilizer content) for the product under study at temperature T. Then formula (1) can be written as:

$$\log c/t = aT + b \qquad \text{or}$$

$$T = -1/a \log t + 1/a (\log c - b) \qquad (3)$$

Formula (3), represents Berthelot's mathematical expression of the deterioration phenomena, which is a straight line function. By referring back to the experimental data plotted for each propellant formulation at the various test temperatures, the points α_x, representing the times for the consumption of a specific amount of stabilizer can be extracted. If these experimental data then satisfy Berthelot's Law, this will be shown by plotting these points (α_x) with T as ordinate and log t as abscissa, and the development of a family of straight lines. This will characterize the length of time necessary for the propellant to consume 10, 20, 30, 40 and 50% of the initial amount of its stabilizer. These graphical expressions for M6, M9, M30 and M10 propellant formulations are shown in Figures 9, 10, 11 and 12 respectively. In viewing the graphs for the M6, M9 and M30 propellants, it is evident that the experimental data conforms quite satisfactorily with Berthelot's Law. However, the results for the M10 Propellant show lines of varying slopes, indicating a change in the reaction mechanism for certain temperature intervals. It is felt that these variations are not so critical as to prevent the determination and use of an average slope for the M10 Propellant. The slope of these lines can be defined by a coefficient gamma (γ_{10}) corresponding to the increase of the reaction rate for a temperature change of 10°C. Therefore, to determine γ_{10}, it is sufficient to take the duration t_1 and t_2 corresponding to a temperature difference $(T_2 - T_1) = 10°C.$, where $\gamma_{10} = t_1/t_2$.

Mathematically, it can be shown that equation (4) below can be derived from (3)

$$T_2 = -1/a \log t_2 + 1/a(\log c-b)$$

$$T_1 = -1/a \log t_1 + 1/a(\log c-b)$$

$$T_2-T_1 = 1/a \log t_1/t_2$$

$$\log t_1/t_2 = a(T_2 - T_1)$$

By setting $\gamma_{10} = 10^{10a}$

Then log $t_1/t_2 = \log \gamma_{10} x\ (T_2-T_1)/10$

and that $t_1/t_2 = \gamma_{10}^{\frac{T_2-T_1}{10}}$ (4)

Therefore, by knowing points (α_x) and the slope γ_{10}, then

$$D_x = \frac{\alpha_x \gamma_{10}^{\frac{T_2-T_1}{10}}}{365} \qquad (5)$$

where α_x is the time, in days, necessary for obtaining an X% decrease in stabilizer content at T_2, γ_{10} is the increase of the rate of reaction for a 10°C. temperature change, and D_x is the prediction of safe life expressed in years to obtain an X% decrease in stabilizer content at T_1.

The literature reveals that investigators have used both Berthelot's and Arrhenius' Laws freely to represent propellant deterioration phenomena. Table 1 shows that there are similarities in their graphic expressions, but also shows differences, mainly in their linear representation of T.

TABLE 1

Representation of Arrhenius' and Berthelot's Law

	Formula	Representation: K	Representation: T
Berthelot	Log K = aT + b	Log Scale	Linear Scale
Arrhenius	Log K = a-b/T	Log Scale	1/T, Linear Scale

As a matter of interest, a formula similar to equation (5) can be derived from Arrhenius' Equation, which employs the data to determine the activation energy (E) rather than Berthelot's coefficient (γ_{10}). Since it is not possible to determine exactly which of these two equations is more appropriate to describe the deterioration of propellants, the choice is left to the discretion of the investigator.

When the data were graphically expressed for both laws as shown in Figure 13, it was found that the predicted safe life of the propellant according to Arrhenius' Law was much longer. Therefore, since this study is related to propellant safe life prediction and safety in storage of propellant stocks, the use of Berthelot's Law for this application is preferred.

The calculated life duration is only a crude approximation of the real life. Coefficients α_x, γ_{10} and D_x have mainly a comparative value, but at the present time they represent a method of estimating the chemical stability of a given composition. In order to verify the agreement between the experimental results and the decomposition under normal storage conditions, formula (5) has been applied to several propellants of different ages. This data is presented in Table 3 and shows that ageing has resulted in the loss of stabilizing potential (X%). By referring to any of the high temperature deterioration rate curves developed for these propellants, the time necessary for the loss of X% stabilizing potential (α_x) can be determined. The coefficient γ_{10} has beer established for these formulations as shown; therefore, by substituting these values into formula (5) the time necessary to obtain the same stabilizer decrease (D_x) at 20°C. (ambient conditions) can be calculated. The relative agreement between the experimental results and the actual ages of the propellants would indicate that this technique is an aid in predicting the safe life of propellants. In the field of propellant stability there are many applications of this predicting technique. A few of these applications are enumerated and discussed below.

In the work dealing with NATO activities, it was assumed that a 60 day storage period at 65.5°C. could be equated to 5 years storage for a propellant, regardless of formulation, at ambient conditions. It was also assumed that new propellant formulations containing 1.00% stabilizer or less should retain no less than 0.3% of that stabilizer after 60 days storage at 65.5°C. in order to be acceptable. Similarly, propellant formulated with more than 1.00% stabilizer should retain at least 0.5% under the same storage conditions.

This study has established that the deterioration rates of propellants of different formulation stored at both high and low temperatures vary greatly; nonetheless it can be shown that the criteria established by the NATO countries are not unrealistic and provide for an ample safety margin in their favor. Working with the most extreme case of all the propellants tested during this study, the M30 Propellant, and calculating its equivalency, ambient temperature storage (20°C.), based on 60 days at 65.5°C., results in a prediction of 8 years. This indicates that the 5 year assumption is reasonable. The lower acceptance limits established are also reasonable and safe, since it has been determined that propellants approach hazard at a 0.1% stabilizer residue.

As stated earlier, the 65.5°C. Surveillance Test is conducted continuously on each and every lot of artillery propellant manufactured for the U. S. Army. In addition, many lots of small arm and rocket propellants are undergoing the same test. In all, there are currently approximately 22,000 lots being evaluated. For some new and stable propellants the length of time necessary for the appearance of red fumes may be in excess of 5 years, as is probable for the M6 formulation, while other formulations are less heat resistant and fume much sooner. Since many years of effort and much repetitive testing is required to maintain the necessary control over these propellant stocks, there is an urgent need for a relatively short term, reliable test to aid in the prediction of safe storage life for all propellants.

It is relatively easy to link the fume time with the change in stabilizer content, since experience has shown that the red fumes of nitrogen dioxide appear very shortly before the propellant has consumed the entire amount of available stabilizer. For convenience we shall call α_N the time elapsed until the appearance of red fumes, and it can therefore be written that α_{100} is greater than or equal to α_N at any high temperature storage condition. The fume times for the M6 Propellant were recorded at various temperatures and when this data is plotted, as shown in Figure 9, it is noted that the slope of this α_N line differs from the other lines, indicating that the reaction mechanism for the overall depletion of stabilizer content is different than the initial through the loss of 50% stabilizer. This fact is particularly evident in the rate curves developed for the M6 Propellant as well as for all the formulations, regardless of the stabilizer involved. This information is of particular interest if used for the prediction of fume times applicable to the 65.5°C. Surveillance Test and enables the currently used surveillance test to be simplified.

Triple-base formulations have, since their inception, presented problems in their safe life control. These propellants do not produce the red fumes of nitrogen dioxide when tested under the conditions cited for the performance of the 65.5°C. Surveillance Test. Therefore, control by means of this test is not maintained through fuming but rather by the appearance of evidence of physical breakdown of the propellant grain. This is not entirely satisfactory. The introduction of this newly developed technique into the surveillance activities offers a distinct advantage in the safe life control over these formulations.

CONCLUSIONS

Analysis of stabilizer content and kinetic interpretation of the resulting data provide a testing technique for measuring the chemical stability of propellants and a tool for forecasting safe storage life.

RECOMMENDATIONS

It is recommended that work of this nature be expanded to include a more comprehensive coverage of propellants of U. S. Army interest. It is also suggested that in future work much closer temperature control be maintained in the high temperature storage chambers, and studies be made to evaluate the extent of temperature control required. In addition, future work should employ supplementary analytical techniques such as thin layer and gas chromatography to evaluate the benefits that might be realized from additional knowledge of the type and concentration of degradation products of the stabilizers involved. Finally, it is recommended that this work and any additional work be closely correlated with propellant surveillance efforts currently in progress at this Arsenal in an effort to coordinate and evaluate the test data pertaining to propellant safe life.

REFERENCES

1. Clear, Arthur J., "Standard Laboratory Procedures for Determining Sensitivity, Brisance, and Stability of Explosives, Picatinny Arsenal Technical Report 3278 Rev. 1, April 1970.

2. Department of the Army Supply Bulletin SB 742-1300-2, "Charge, Propelling, Various Propellant, Bulk Ammunition Surveillance Procedures", 28 July 1971.

3. MIL-STD-286B, Notice 2, Method 201.4.2, "Propellants, Solid: Sampling, Examination and Testing", dated 30 June 1971.

4. Tranchant, J., "Contribution a L'Etude des Proprietes' Chimiques et Physico-Chimiques des Poudres", Memorial des Poudres 44, Annexe (1962).

5. Tranchant, J. and Brun, J., "Etude Generale de la Stabilite' Chimique des Poudres", Memorial des Poudres 41, 189 (1959).

TABLE 2

Propellant Compositions

Ingredients, %	Propellant Type: M6	M10	M9	M30
Nitrocellulose	87.00	98.00	57.25	28.00
Nitroglycerin			40.00	22.50
Nitroguanidine				47.70
Dinitrotoluene	10.00			
Dibutylphthalate	3.00			
Diphenylamine	1.00*	1.00		
Ethyl Centralite			0.75	1.50
Potassium Sulfate		1.00		
Potassium Nitrate			2.00	
Cryolite				0.30
Graphite		0.10**	0.15*	

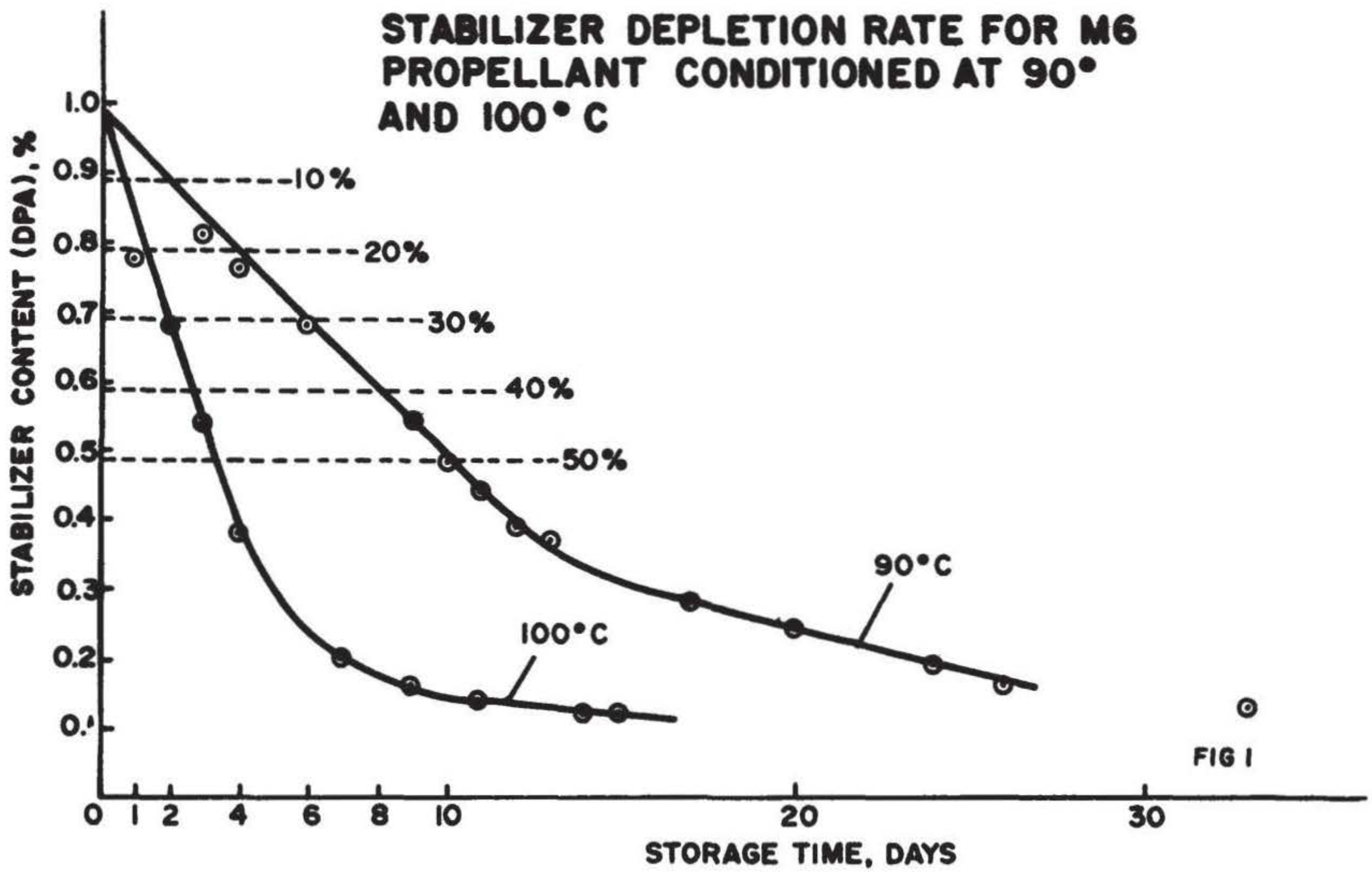
*Added

**Glazed

TABLE 3

Prediction of Propellant Safe Life

Propellant Type	Stabilizer Loss, %	γ_{10}	α_x, Days at T_2	D_x, Years	Actual Age, Years
M1	10	3.83	12.5 at 70°C.	25	28
M1	11	3.83	14.5 at 70°C.	25	33
M6	13	3.29	2.5 at 90°C.	21	29
M6	15	3.29	2.9 at 90°C.	34	33
M5	8	3.75	1.3 at 80°C.	7	10
M5	9	3.75	1.5 at 80°C.	7	11
M7	5	4.49	0.2 at 90°C.	18	20


STABILIZER DEPLETION RATE FOR M6
PROPELLANT CONDITIONED AT 90°
AND 100° C
STABILIZER CONTENT (DPA), %
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
10%
20%
30%
40%
50%
90°C
100°C
FIG I
0
1
2
4
6
8
10
20
30
STORAGE TIME, DAYS

STABILIZER DEPLETION RATE FOR M6 PROPELLANT CONDITIONED AT 60°, 70°, AND 80° C

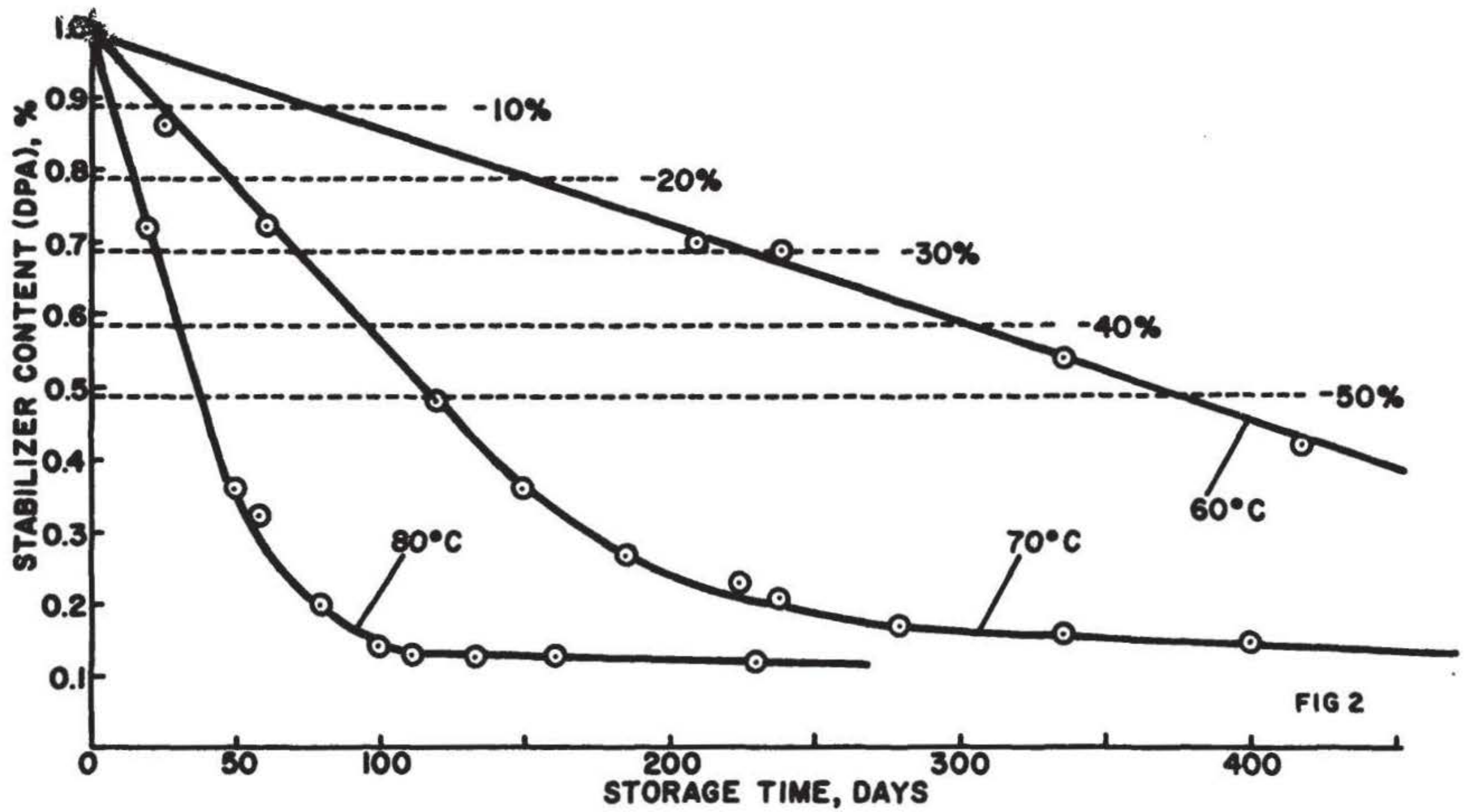
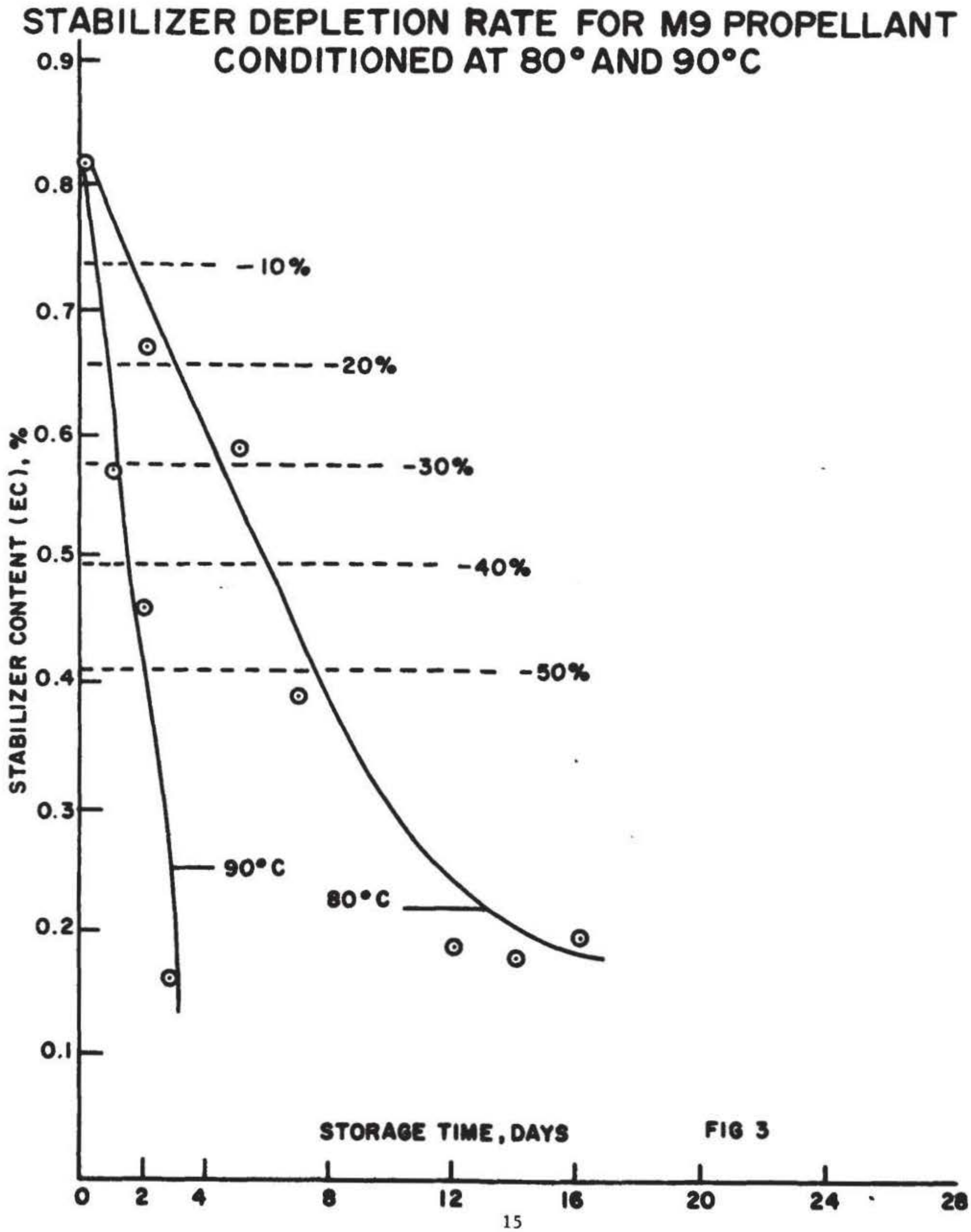


FIG 2



STABILIZER DEPLETION RATE FOR M9 PROPELLANT
CONDITIONED AT 80° AND 90°C
STABILIZER CONTENT (EC), %
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-10%
-20%
-30%
-40%
-50%
90°C
80°C
STORAGE TIME, DAYS
0
2
4
8
12
16
20
24
28

FIG 3

004381

STABILIZER DEPLETION RATE FOR M9 PROPELLANT CONDITIONED AT 60° AND 70°C

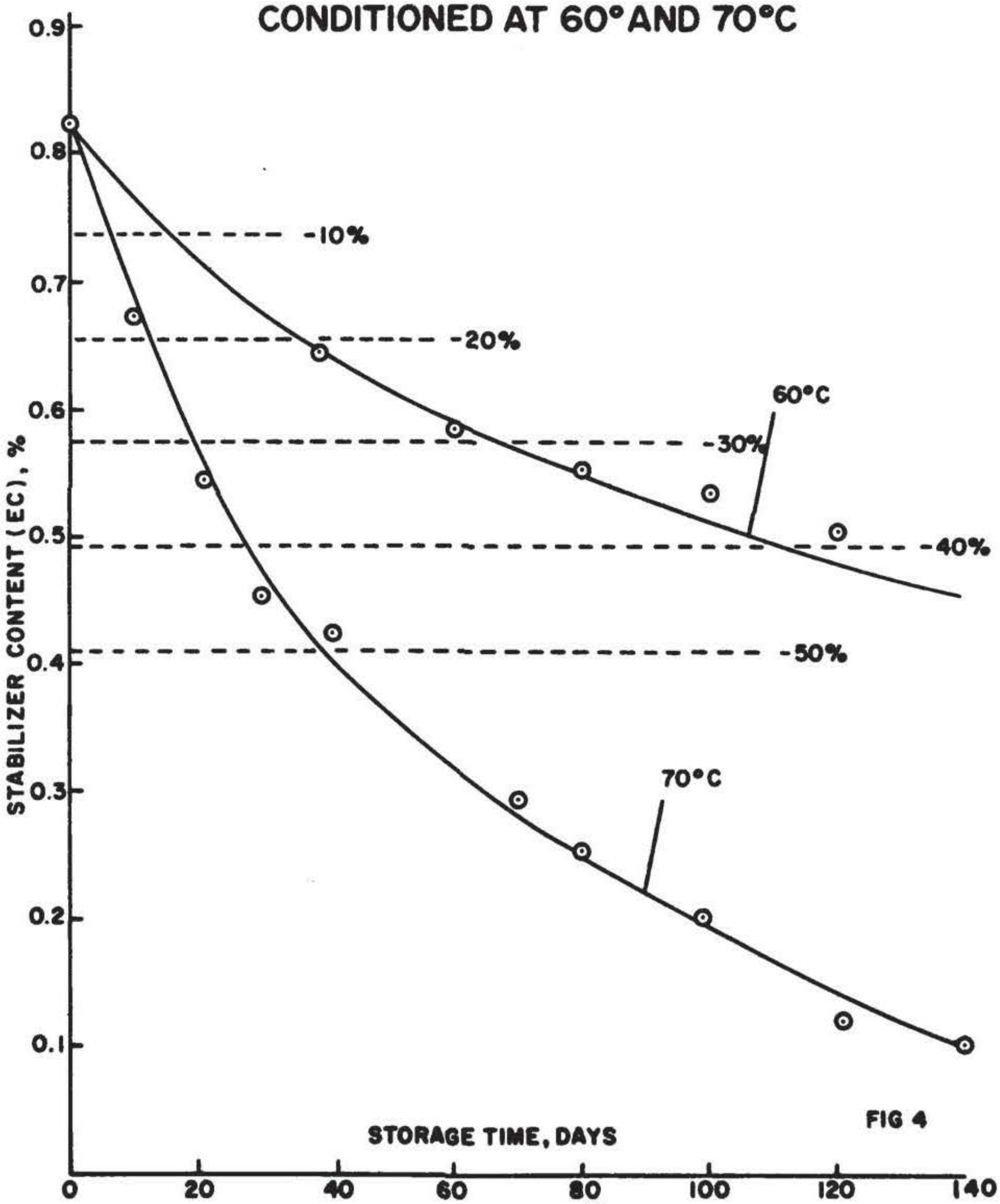


FIG 4

004382

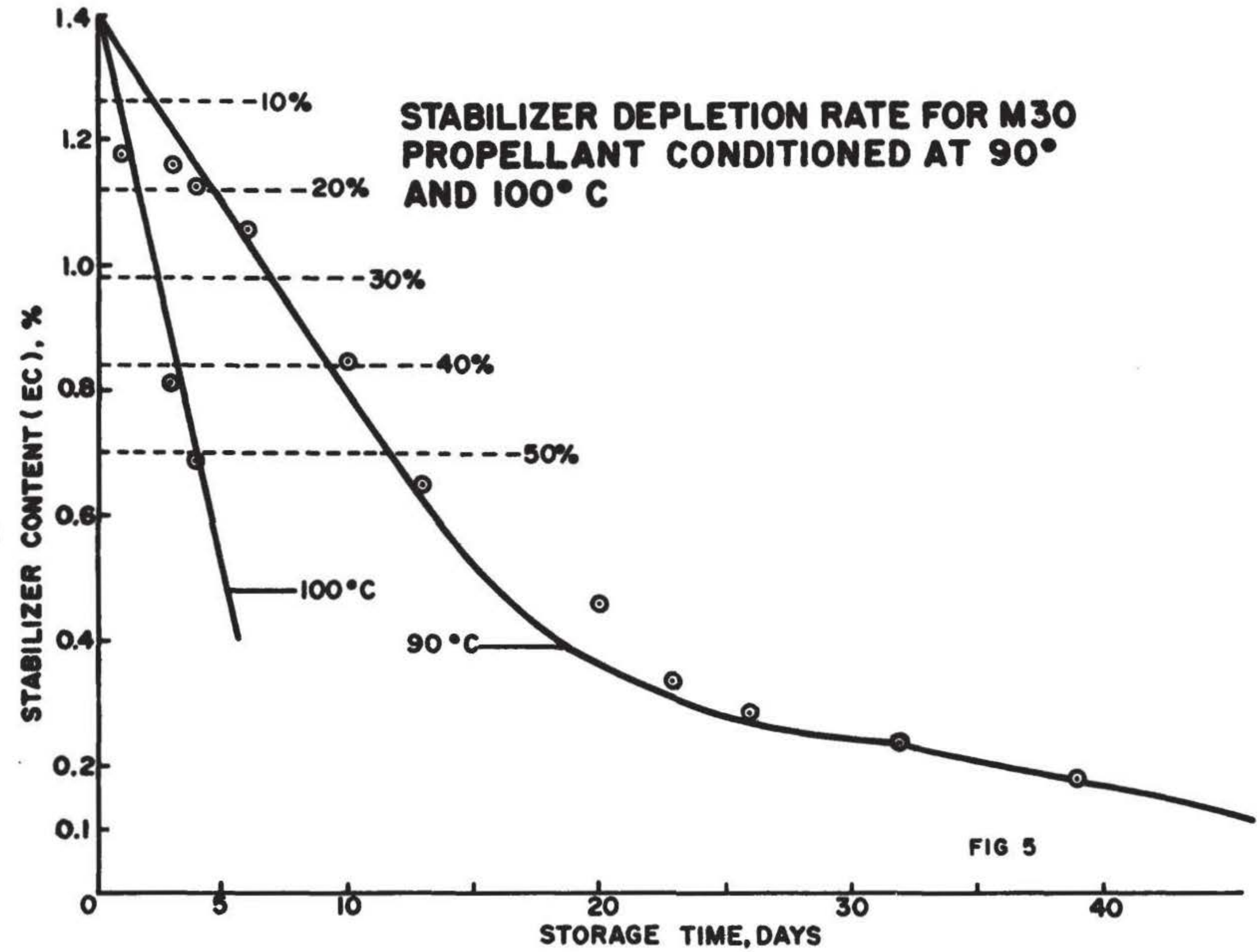

STABILIZER DEPLETION RATE FOR M30 PROPELLANT CONDITIONED AT 90° AND 100° C
STABILIZER CONTENT (EC), %
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.1
10%
20%
30%
40%
50%
100°C
90°C
0
5
10
20
30
40
STORAGE TIME, DAYS

FIG 5

004383

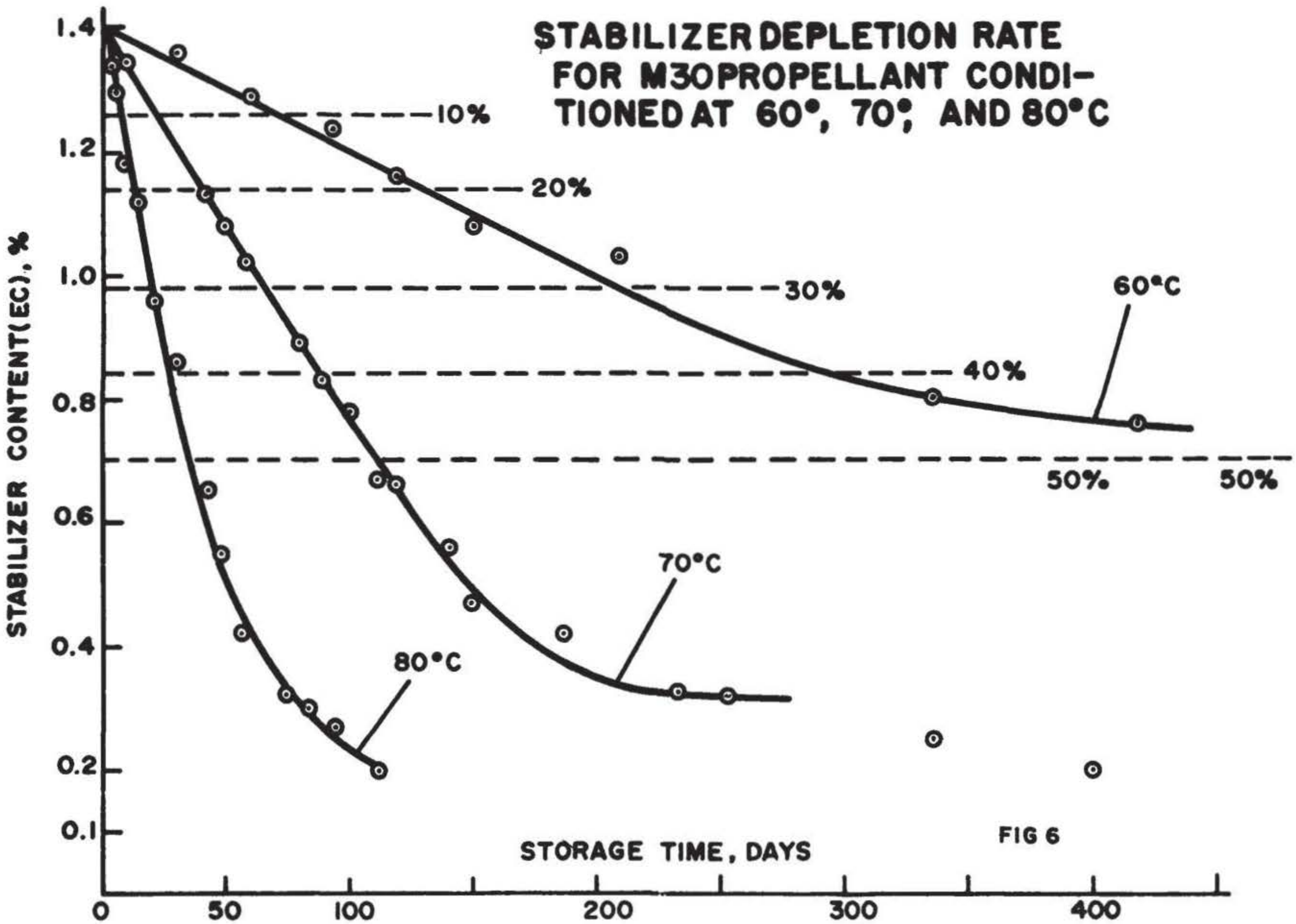

STABILIZER DEPLETION RATE FOR M30 PROPELLANT CONDITIONED AT 60°, 70°, AND 80°C
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.1
STABILIZER CONTENT (EC), %
10%
20%
30%
40%
50%
50%
60°C
70°C
80°C
STORAGE TIME, DAYS
0
50
100
200
300
400

FIG 6

004384

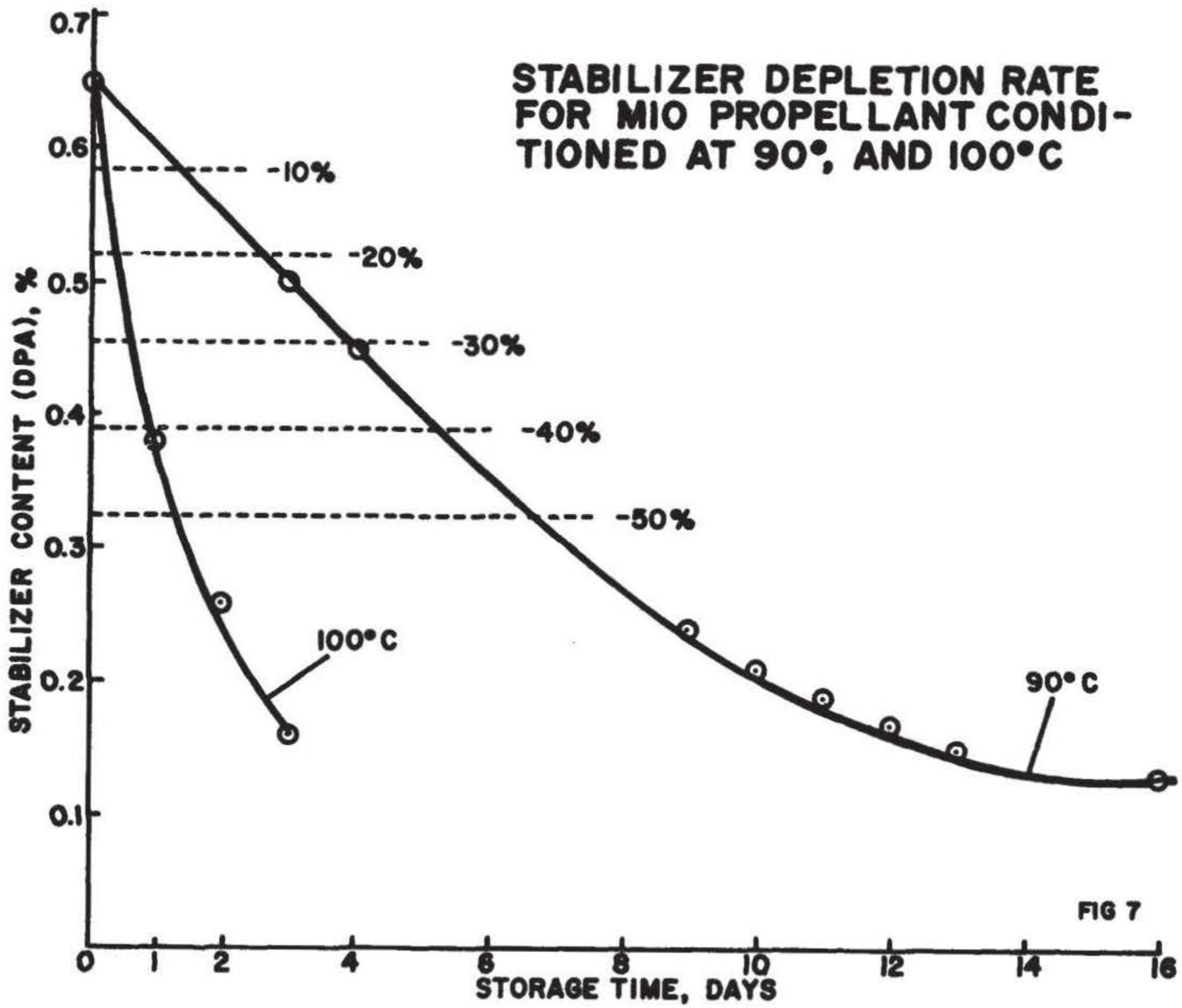

STABILIZER DEPLETION RATE FOR MIO PROPELLANT CONDITIONED AT 90°, AND 100°C
STABILIZER CONTENT (DPA), %
STORAGE TIME, DAYS
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
4
6
8
10
12
14
16
-10%
-20%
-30%
-40%
-50%
100°C
90°C

FIG 7

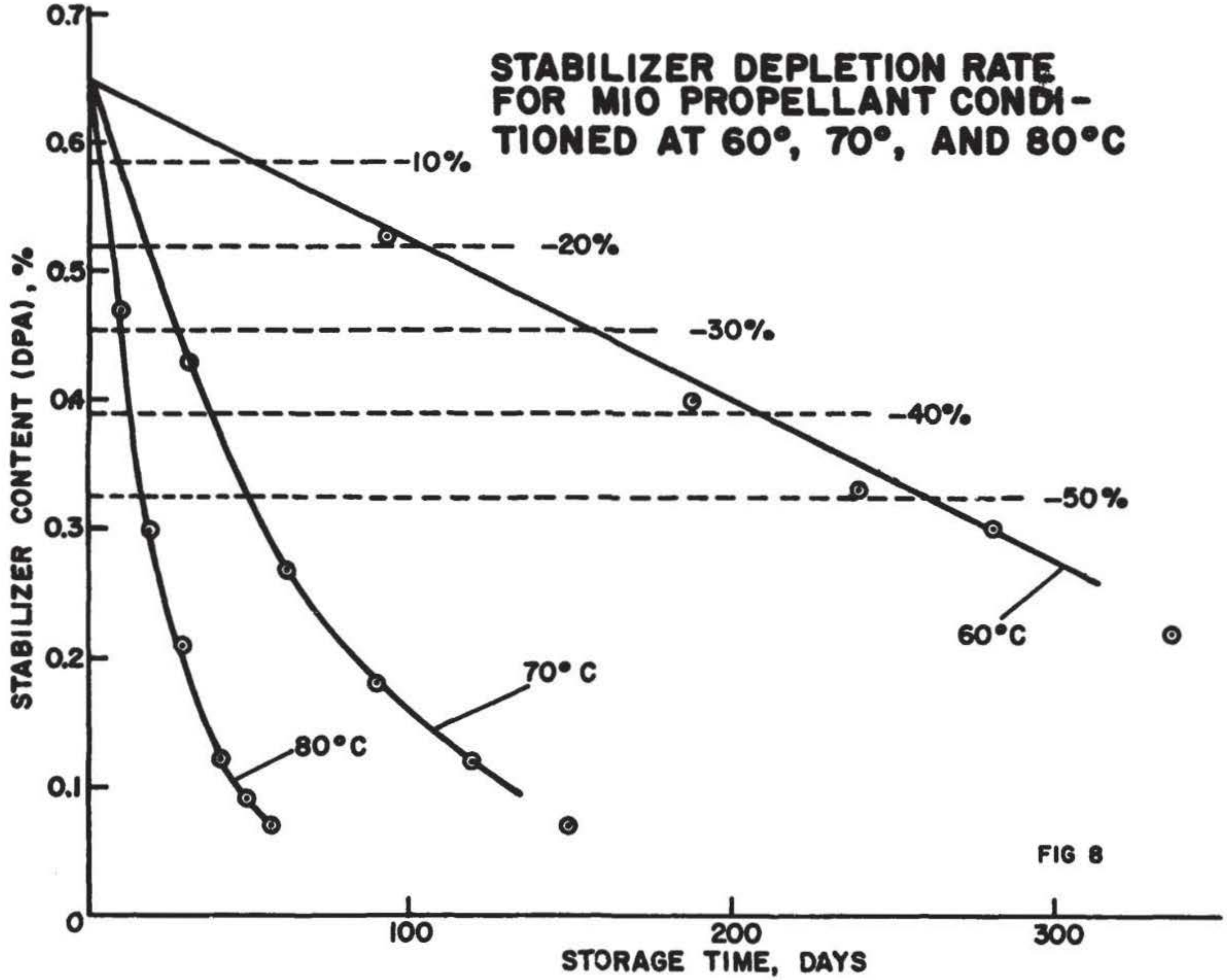

STABILIZER DEPLETION RATE FOR MIO PROPELLANT CONDI-TIONED AT 60°, 70°, AND 80°C
STABILIZER CONTENT (DPA), %
STORAGE TIME, DAYS
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
200
300
-10%
-20%
-30%
-40%
-50%
60°C
70° C
80°C

FIG 8

DETERIORATION PHENOMENA EXPRESSED BY BERTHELOT'S LAW FOR M6 PROPELLANT

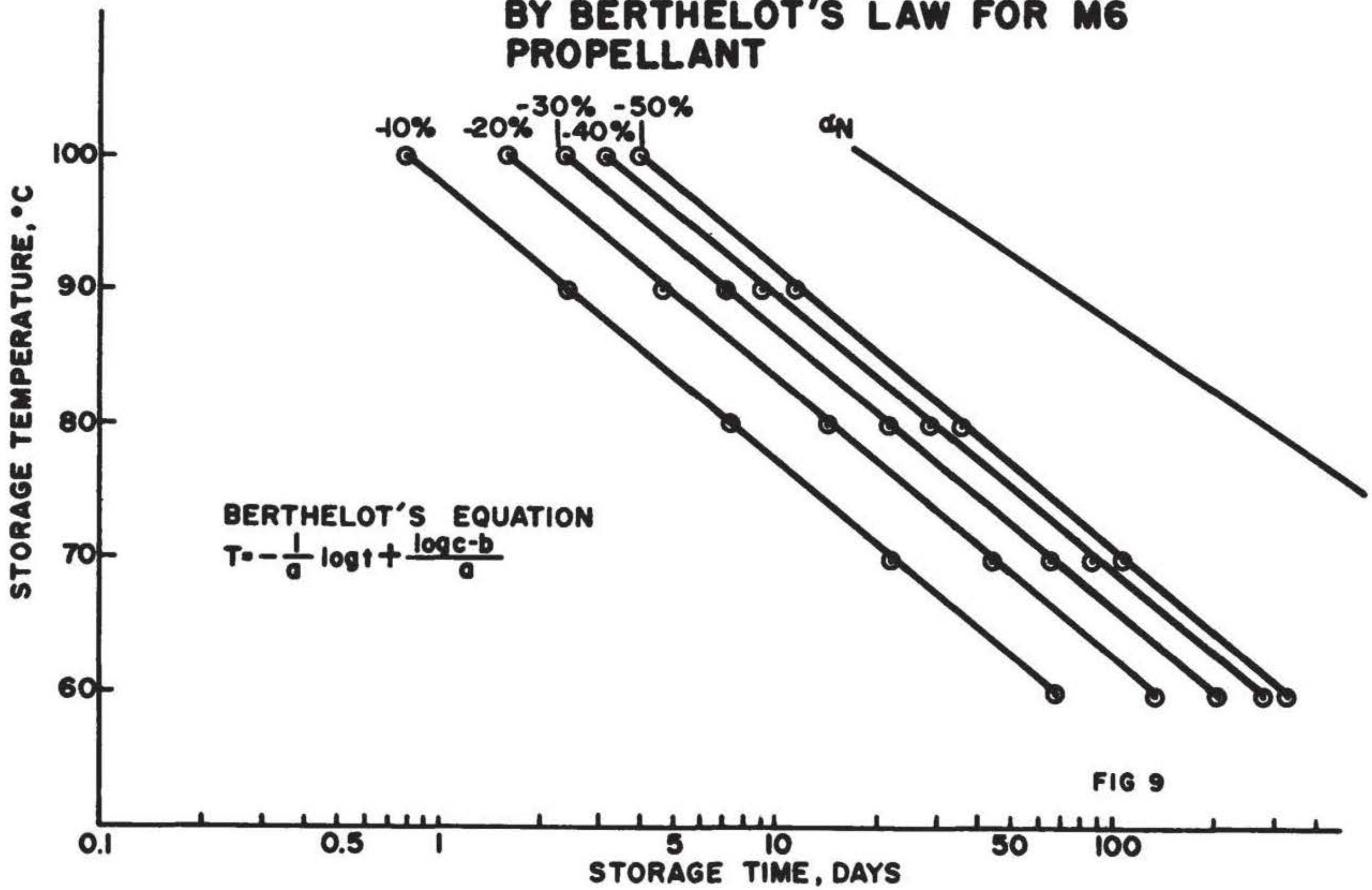


FIG 9

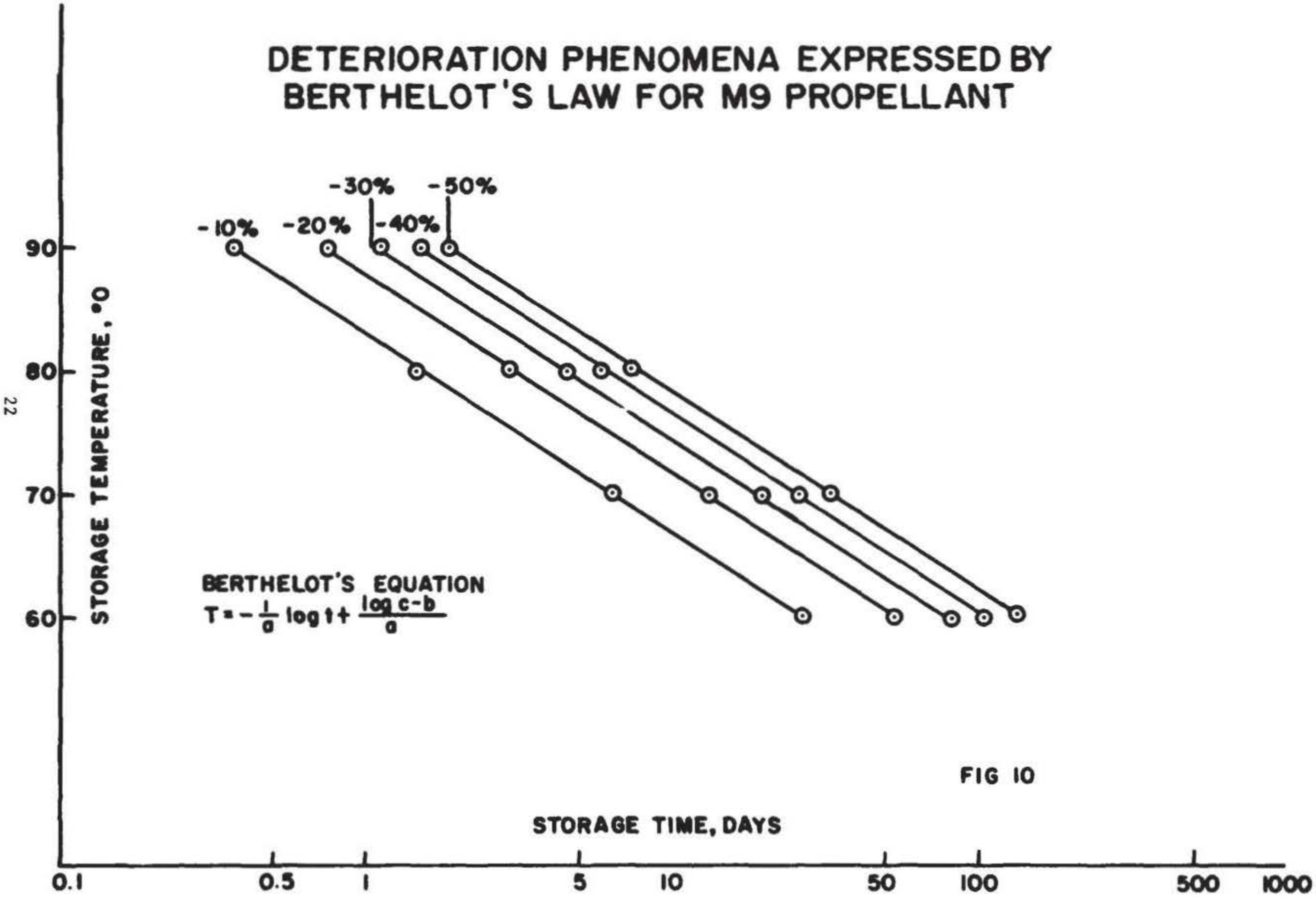


FIG 10

004388

DETERIORATION PHENOMENA EXPRESSED BY BERTHELOT'S LAW FOR M30 PROPELLANT

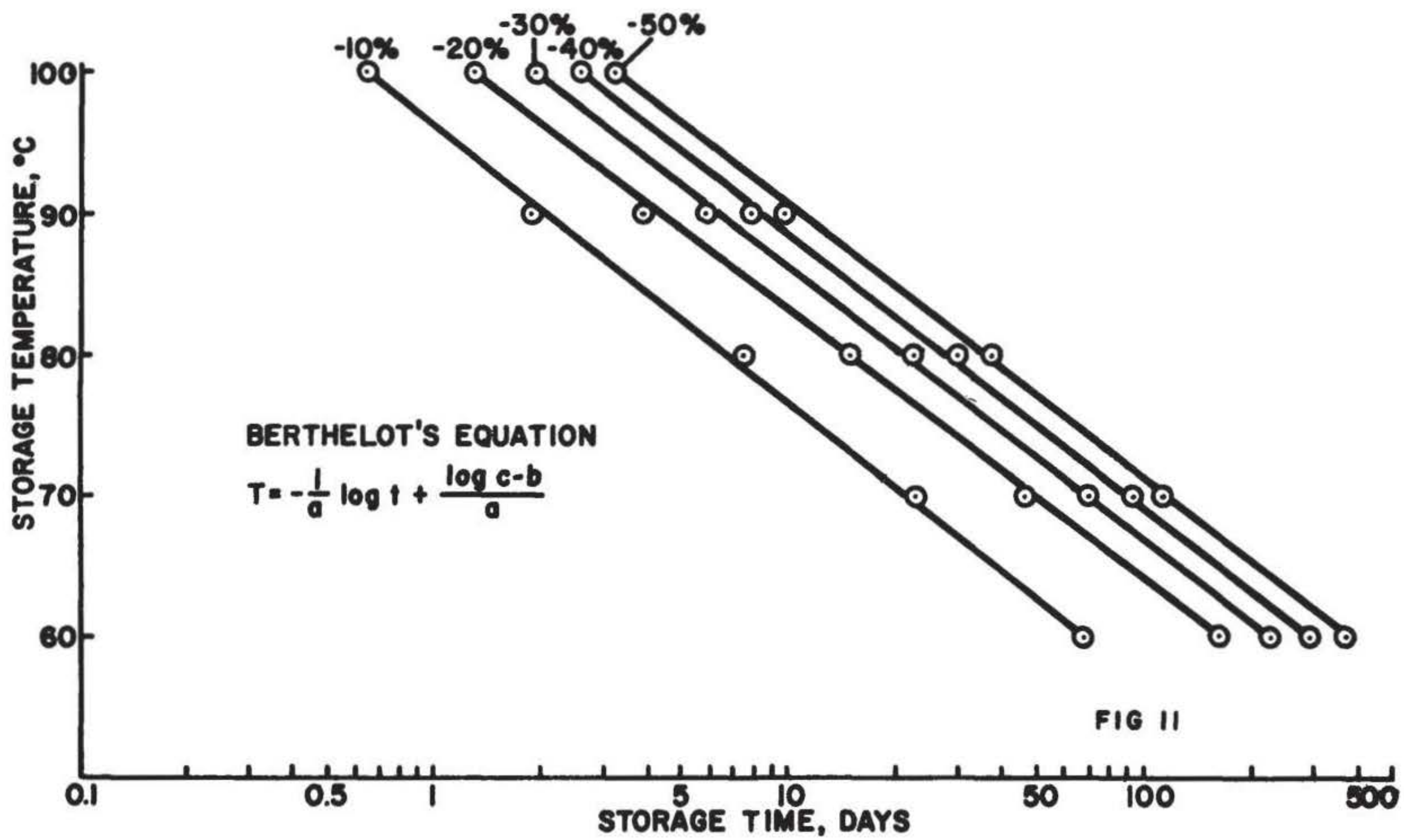


FIG 11

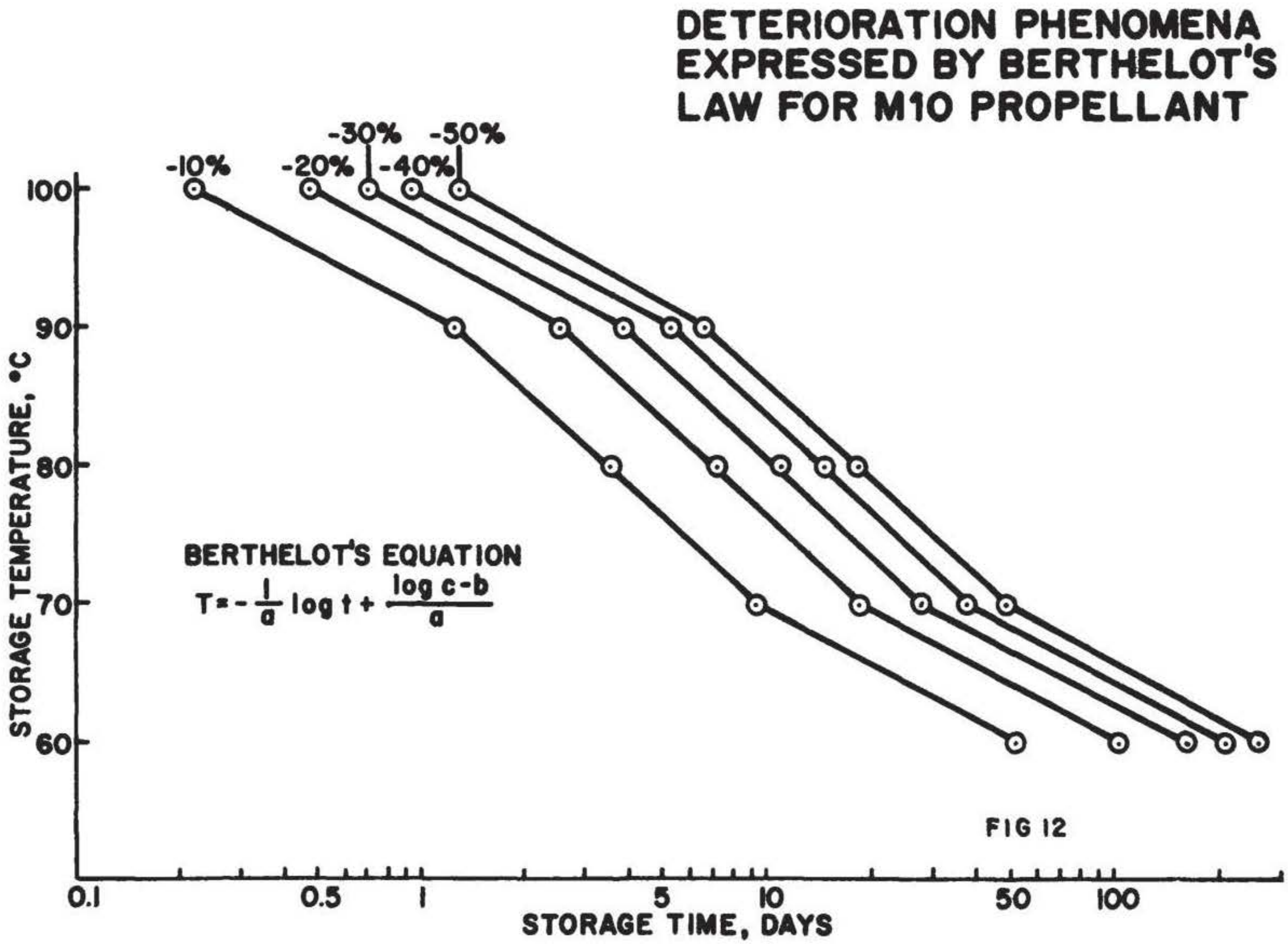

DETERIORATION PHENOMENA EXPRESSED BY BERTHELOT'S LAW FOR M10 PROPELLANT
-10%
-20%
-30%
-40%
-50%
100
90
80
70
60
STORAGE TEMPERATURE, °C
BERTHELOT'S EQUATION
$T = -\frac{1}{a}\log t + \frac{\log c - b}{a}$
0.1
0.5
1
5
10
50
100
STORAGE TIME, DAYS

FIG 12

COMPARING DATA FROM ARRHENIUS VS BERTHELOT'S EQUATIONS

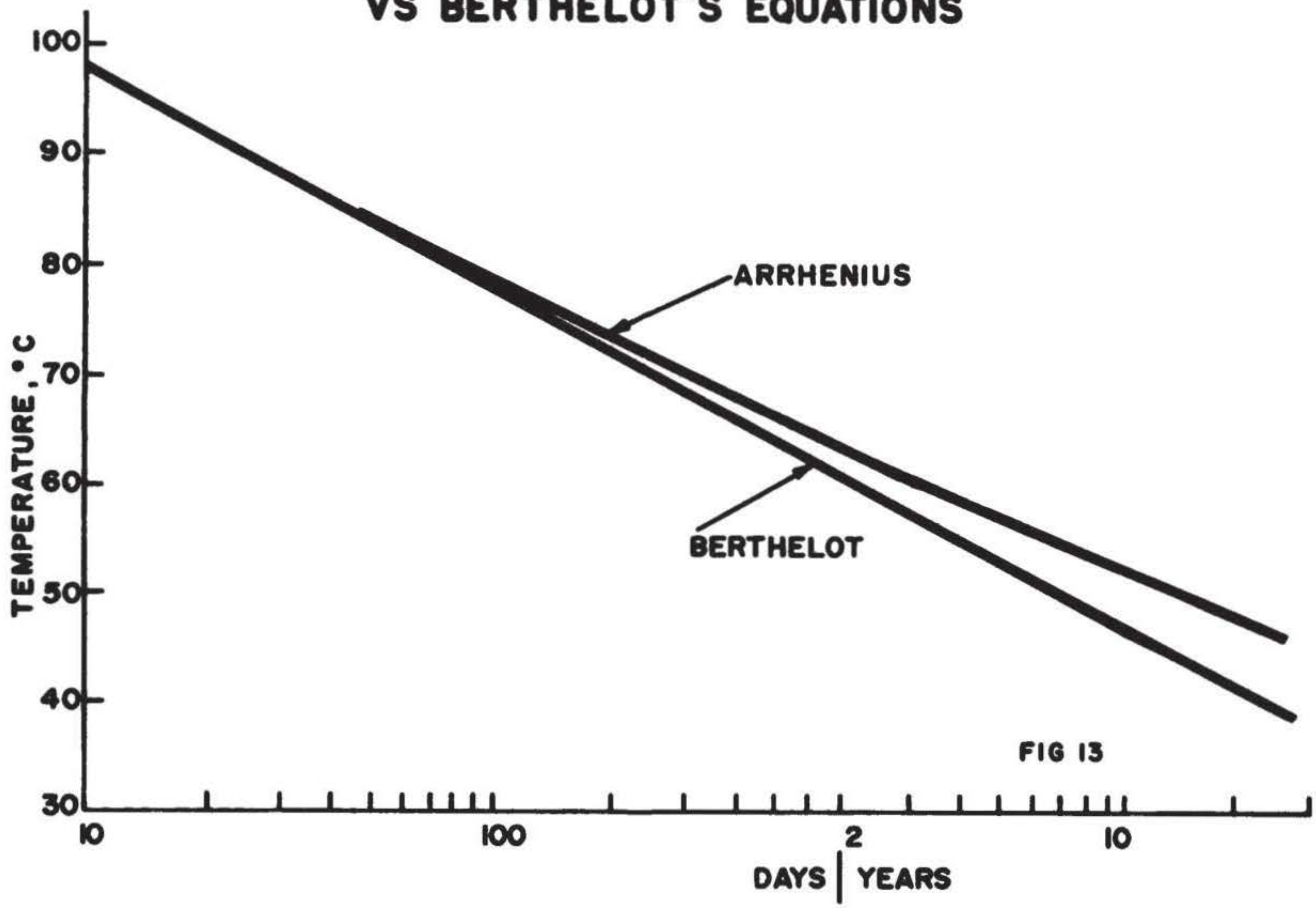


FIG 13

25

004391

Logistics Review and
Technical Assistance Office

June 1998

PROPELLANT MANAGEMENT

GUIDE

Prepared By:
U.S. Army Defense Ammunition Center
Logistics Review and Technical Assistance Office
Savanna, Illinois 61074-9639

FORGING A STRONG DEFENSE

004392

U.S. ARMY INDUSTRIAL OPERATIONS COMMAND
ROCK ISLAND, IL 61299-6000

PROPELLANT MANAGEMENT GUIDE

JUNE 1998

1. In this guide, the U.S. Army Defense Ammunition Center is presenting methods and procedures to aid in the application of the various propellant test programs applicable to our storing installations.

2. We've derived information contained in this publication from U.S. Army Supply Bulletins and Technical Manuals; from the Army Propellant Program Manager at U.S. Army Industrial Operations Command, Rock Island, Illinois; the U.S. Army Propellant Surveillance Laboratory at Picatinny Arsenal, New Jersey; and the U.S. Navy's Naval Surface Warfare Center – Indian Head Division, Indian Head, Maryland. We do not intend for this publication to supersede, contravene, or modify any of these publications or information sources.

3. This publication's intent is to provide the user at a storing installation with essential information for the effective and safe management of propellant and propelling charges. We encourage your comments and suggestions regarding this publication. Furnish your comments to Director, U.S. Army Defense Ammunition Center, ATTN: SIOAC-AV, Savanna, IL 61074-9639, or via E-mail to: gravese@dac-emh1.army.mil.

JAMES W. MONROE
Major General, USA
Commanding

31 JUL 1998

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Contents

Contents (Continued)

CHAPTER 1

INTRODUCTION

1-1. PURPOSE

This guide provides information and methods for the safe and efficient storage and management of propellants and propelling charges. It supplements information contained in SB 742-1, SB 742-1300-94-895, TM 9-1300-214, SW020-AE-SAF-010 and other sources. Rocket/Guided Missile propellants are not addressed.

1-2. SCOPE

The guidance contained herein may be used by U.S. Army installations which have a receipt, issue and storage mission for Class V materiel.

1-3. BACKGROUND

a. The mere physical presence of propellant at a given location creates interest and concern. Among commonly stored energetic materiels, only nitrate ester-based propellants (principally nitrocellulose-based ones) have the propensity to self-ignite (autoignite) without warning while in static storage; catastrophic losses can result. Artillery and Small Arms propellants are perhaps the most dangerous and suspect materials that Army installations regularly and routinely handle and store. Propellant can be unpredictable, decomposing into an unstable condition within four or five years of manufacture. Inadequate propellant safety programs have contributed to several self-ignition incidents at U.S. Army installations.

b. When grains, sticks or sheets of propellant inside a container ignite, sufficient heat and flame is produced to ignite the remaining propellant material in that container. If unstable propellant is present in the smallest amounts (even a single container), its combustion will probably ignite the contents of the entire structure. The propellant burns at a very rapid rate in a process that is known as *deflagration*. Deflagration differs significantly from *detonation* in that deflagration involves very rapid combustion that takes place on the surface and proceeds into the grain; it proceeds the same as normal burning, but at a very accelerated pace. Detonation, on the other hand, occurs due to a completely different process which involves a shock wave moving at supersonic speeds through the explosive material, thereby causing its decomposition. Therefore, *deflagration* operates on the basis of heat transfer, while *detonation* operates on the basis of a shock wave.

(1) During the period 1984 through 1989, five propellant self-ignition events occurred at U.S. Army Materiel Command (AMC) installations. These deflagrations began with the Lake City AAP accidents in 1984 which resulted in the loss of two storage magazines and contents. Other incidents of propellant autoignition resulting in total magazine loss include the 1985 Blue Grass Army Depot event, and a 1987 accident at Lone Star AAP. Another self-ignition accident

at Hawthorne AAP in 1989 involved a relatively small number of Navy separated charges and resulted in damage to, but not destruction of the storage magazine.

(2) Seven years separated the last of the '80's fires with those of the '90's: the 1996 autoignition of M10 powder at Red River Army Depot, and almost exactly one year later, in 1997, a deflagration at Hawthorne Army Depot which was much more devastating than the self-ignition incident which they experienced in 1989.

1-4. ENDORSEMENT FOR USE

Information in the following pages provide the essentials for safe management of your propellant. This LRTAO Information Pamphlet, endorsed by the Propellant Safety Surveillance Board (a Joint Services organization), offers reasonable procedures and guidelines for responsible organizations to effectively manage and safely control in-storage assets of bulk propellant and propelling charges.

CHAPTER 2

PROPELLANT STABILITY PROGRAM

__NOTE:__ Most of the instructional provisions of Chapter 2 do not apply to Navy-owned/developed gun propellants. Special provisions for Navy propellant are found in Chapter 4.

2-1. THE PROPELLANT STABILITY PROGRAM

The Propellant Stability Program (PSP) is a sub-program of the Stockpile Laboratory Test Program (SLTP). The SLTP is one of the three major sub-programs of the Department of Army-directed Ammunition Stockpile Reliability Program (ASRP).

The purpose of the PSP is to provide surveillance of propellant stability through:

a. Constant predictive laboratory surveillance

b. Periodic chemical analysis of stabilizer content

2-2. DEFINITION: STABILIZERS

STABILIZERS are chemical ingredients added to propellant to prevent autoignition during the the propellant's expected useful life.

...EXPLANATION: As nitrate ester-based propellants decompose, they release nitrogen oxides. If the nitrogen oxides are left free to react in the propellant, they can react with the nitrate ester, causing further decomposition and additional release of nitrogen oxides. The reaction between the nitrate ester and the nitrogen oxides is exothermic, i.e. the reaction produces heat. The exothermic nature of the reaction creates a problem if sufficient heat is generated to initiate combustion. Chemical additives, referred to as *stabilizers*, are added to propellant formulations to react with free nitrogen oxides to prevent their attack on the nitrate esters in the propellant. The stabilizers are scavengers that act rather like sponges, and once they become "saturated" they are no longer able to remove nitrogen oxides from the propellant. At this point self-heating of the propellant can occur unabated. Once begun, the self-heating *may* become sufficient to cause *autoignition.*

2-3. COMPONENT PROGRAMS OF THE PSP

Propellants which are known to be in the ammunition stockpile stored by the Army are monitored and tested for stability. Installations are provided with the information necessary to make sound storage decisions. The PSP produces this information through its two component programs, the *Master Propellant Program* and the *Stockpile Propellant Program*.

2-4. MASTER PROPELLANT PROGRAM (MPP)

a. The oldest continuous Class V laboratory test program within the Army, the Master Propellant Program (sometimes referred to as the Master "Sample" Program) has operated continuously at Picatinny Arsenal for over 75 years, having begun in 1921.

(1) Producers of Army propellant are required to submit a 5-pound master sample within 6 months of manufacture to the Armament Reasearch and Development Center (ARDEC) at Picatinny Arsenal. Until the mid-1990's, a tiny portion from each of the newly received samples would be placed under continuous monitoring inside one of eight large, circular ovens as part of the 65.5 degree Celsius Accelerated Aging Test (AAT). Today, a new Safe Interval Prediction (SIP) test, also conducted at 65.5^0C, is replacing the time-honored AAT due to the new test's capability to provide usable predictive safe storage intervals for the propellant. Predictive evaluation wasn't possible under the old 65.5^0C AAT.

(2) For many years, all types of single and double base propellant were subjected to the 65.5^0C AAT. The samples bottles were usually checked during each duty day for the presence of reddish-brown fumes which indicated that the end of the propellant's stable life was near and could, in fact, be approaching a state of autoignition. Underappreciated during this period was the tendency of many propellant compositions to produce the red fumes and continue to decompose, but after the initial fuming, the fumes would fade and not reappear. So, if a bottle was not checked frequently enough, it was possible that the fuming event would go unobserved. Ultimately this operational shortcoming caught up with Picatinny during the 1970's, when an explosion occurred in a test chamber. The subsequent investigation revealed that each bottle inside each chamber must be visually checked seven days per week, and operational adjustments were implemented. This makes the AAT quite labor intensive. A study of fume times and propellant age revealed that there was no predictive value in those data. The pattern of fume times could not be used to predict propellant safe life or the onset of propellant failure. The test was simply a pass or fail test. The propellant either remained safe or it was no longer safe depending upon a fume time of greater or less than 30 days. Finally, the lack of responsiveness to the AAT by triple base propellant types meant that they could not be tested by the standard procedure. *All* propellant types respond favorably to the new SIP test.

(3) *MPP LABORATORY ACTIVITIES.* The Master Propellant Program generates minimal activity for storing and/or using organizations. Even though it operates seven days per week, personnel at the storing installation level have little contact with the Program, because the test sample quantity seldom requires replenishment, as the initial sample supplied by the manufacturer is usually a sufficient test quantity for the entire stockpile life of the propellant.

b. **65.5^0C ACCELERATED AGING TEST CYCLE:**

(1) Although the test protocols were developed in the 1910's, the Navy AAT facility at Indian Head was established after the First World War in 1921, while a sister program for the Army followed at Picatinny Arsenal later that same year. It was expected that the AAT could be used to predict a propellant's safe storage life by simply "plugging in" the proper ratio of

days-to-fume in the heat chamber to the actual days storage in the ambient environment. Various attempts over the years to impart a predictive meaning for the AAT have met with frustration. In practice, the AAT has not been used successfully in any predictive manner; it is only used to provide a pass/fail stability determination. Attempts to make the test predictive still occur, and someone may eventually be successful.

(2) The AAT is still used to establish a “base line” for newly received propellants. All new master samples are accelerated aged for 160 days to observe fume behavior. This test assures that newly manufactured propellant has no incompatibility or inhomogeneity present that would affect long term stability.

(3) All propellants which are nearing the end of their safe life are AAT'd for 45 days to observe for possible 30 day fume failures. This procedure allows full compliance with existing Tri-Service criteria.

(4) If the fume time is short (30 days or less) or an unusual result is indicated on an individually tested sample, the propellant lab conducts an analysis of the propellant to determine the percentage of remaining effective stabilizer (RES) to better determine the safety status of the propellant.

(5) If this test, in conjunction with the 65.5^{0}C results, confirms the impending instability of the propellant, the program manager at IOC, Ammunition Surveillance Division, is immediately notified.

c. **SAFE INTERVAL PREDICTION TEST:**

(1) The SIP test uses zero order reaction kinetics to assess the safe storage condition on all of the Army's 30-plus types of propellant in its inventory. The test generates its own safe storage and retest interval on a lot-to-lot basis.

(2) The test measures the decrease of virgin stabilizer using High Performance Liquid Chromatography (HPLC) at regular intervals. The test is run at 65.5^{0}C, like the AAT. Each sample also is tested prior to aging and the level of remaining effective stabilizer (RES) is determined.

(a) The SIP test is designed to provide the retest intervals normally provided by the certain, yet often capriciously unpredictable fume event. The kinetic calculations estimate the time required to deplete the effective stabilizer to zero concentration. Routinely, fume times for a single propellant lot vary greatly from one cycle to another; the intervals can decrease over time and then increase before failure occurs. The *advantage* of the SIP test is that predictable behavior is being measured that relates chemically to what we understand to be the onset of instability.

(b) The SIP test avoids the problems associated with wide variations in the change in the rate of a reaction for each 10 degree change in reaction temperature by using the kinetic data it produces to establish reasonably conservative retest intervals (similar to the widely-accepted NATO method). These intervals are fractions of the typical shelf life of the propellant tested. The SIP test data provides an estimate of the time for the effective stabilizer to be depleted at the aging temperature.

(c) Using this SIP information, plus the known average life of propellants under ambient storage conditions, a reasonable factor is used that provides multiple retests over the life of the propellant. For example, a single base propellant generally has a life of 50 to 75 years. The safe interval predicted by the SIP method is not allowed to exceed 15 years. The method then establishes three to five intervals or more over the life of a typical single base propellant. More and closer intervals are usually required as the propellant ages because the predicted safe interval becomes smaller.

(3) No attempt to predict the entire shelf life of a propellant is made. The retest interval represents a period of time where the rate of reaction is such that the effective stabilizer cannot be brought to a dangerously low level. Sufficient stabilizer will be present at the end of the interval, thus no self-ignition can occur.

(4) The largest test interval allowed is 15 years. The safe storage and retest interval decreases over the life of the propellant, increasing the test frequency as the propellant approaches instability. Additional control measures include:

(a) All Stability Category “C” propellant is tested each year for remaining effective stabilizer level and 30-day fume failure; they are not SIP tested.

(b) Propellants with retest intervals of 3 years or less are not SIP tested.

d. *WHEN MPP STABILITY FAILURE OCCURS.* In the case of indication of stability failure for any of the test methods used on the Master Sample, the IOC, Ammunition Surveillance Division is notified. Normally, one of two actions will occur:

(1) IOC will permanently suspend the propellant lot and transmit a Notice of Ammunition Reclassification (NAR) message which will require *immediate destruction* of that lot when packaged as bulk propellant, bulk component charges, or as separate loading propelling charges.

(2) IOC will review the storage records and determine the impact on the stockpile if the lot is destroyed. If the Master Sample test results are considered to *not* be reflective of actual stockpile conditions, a sample (or samples) may be selected from a storing installation for special test. Any action concerning destruction of the lot will be held in abeyance pending stockpile test results.

NOTE: Master Sample test failure usually results in the destruction of a propellant lot, and the second option is seldom taken.

e. *Storing Installation Surveillance Responsibilities* for the Master Propellant Program are quite limited and usually consist of nothing more than the infrequent preparation of a specified quantity (3-5 pounds) of propellant for shipment to Picatinny Arsenal to replace a depleted or missing Master Sample. This action may involve the disassembly of a propelling charge. Assure the Depot Surveillance Record (DSR) card is annotated to the effect that:

(1) the sample was selected and shipped for the Master Propellant Program

(2) *no action* on the propellant lot is pending; sample selection and shipment for the MPP is simply a shipment. You will *not* receive test results or other feedback.

NOTE: The condition code of the parent lot will *not* change due to the sampling. Do *not* apply "CC-D pending test results" unless specifically directed by IOC.

2-5. STOCKPILE PROPELLANT PROGRAM (SPP)

a. The SPP is the more visible arm of the PSP with which the storing installations have the greatest contact. This test program uses small sample quantities which are provided from propellant lots actually in storage. The samples are packaged and sent to Picatinny Arsenal for laboratory analysis of remaining effective stabilizer. Samples are prepared at the request of the IOC Ammunition Surveillance Division, normally on a once-per-year basis in order to limit the workload burden to the storing installations .

(1) The remaining effective stabilizer (RES) level is determined in duplicate for both the field sample and for the Master Propellant sample. A comparison of the results for the two storage sites for the propellant lot identifies errant behavior in the fielded propellant and provides the basis along with SIP testing of the Master Propellant sample for establishning the next field sampling date for the IOC. This next sample date is based on kinetic data and is a true prediction of future behavior. Testing based on the field retest date is less frequent than past criteria and represents a decreased burdon to the storing installations.

(2) The current RES, safe storage category, and next field test date for all the lots in the Stockpile Propellant Program are available through the World Wide Web. This data base is provided to the IOC by the Army Propellant Surveillance Laboratory and is available through the IOC web site.

b. *Selection, Preparation and Shipment of Samples* will always be as instructed by SB 742-1, SB 742-1300-94-895, or as directed by special instruction (usually received with sample nomination letter) from HQ IOC. Since those instructions are quite specific, this Pamphlet will not elaborate further, except to point out the following:

(1) Most samples will consist of separate loading propelling charges, normally one complete charge per lot requested, although samples will also be requested from bulk propellant and bulk-packed component charges. Some charges (such as the 105mm M67 charge) are of dual-granulation. Dual granulation charges contain two individual lots of propellant per

propelling charge lot. Ammunition Data Cards should be checked to verify if a loaded charge is/is not a dual grain charge.

(2) It is likely that only a few individual propellant grains will be used for test purposes out of the entire one-pound or complete charge which consists of hundreds to thousands of grains. Good sampling techniques should be used. When removing propellant grains from a bulk container or from charge bags, select the sample from a *single location*, and identify that location on the sample baggie for lab personnel (e.g., "Sample Selected from Top of Drum," "...Center of Drum," "from Charge 3 where it abuts Charge 4," etc.). On occasion the excess material provided is used to supplement the Master Sample when it is expended in testing, thus adding to the importance of good sampling, packing and shipping procedures.

(3) You will want to remark on your DSR card that a sample has been selected and prepared for the SPP.

(4) Samples are often held up for shipment for an indefinite period, resulting in a number of samples sitting idle. These samples are sometimes ignored and/or forgotten. This is unacceptable, and the guidance immediately below should be followed.

(5) *Recommend* samples be tracked by a local suspense so that if Materiel Release Orders are delayed or cancelled, the local Surveillance organization will be "flagged" to take some type of closing action on the sample quantities (i.e., local destruction, request disposition from IOC, etc.).

(6) *Immediate destruction of residue is recommended.* If you have generated propellant residue from your sample preparation, assure the residue (remains of propelling charge) is properly repackaged and identified on stock records if returned to storage. Due to recent changes in procedures for disposition of unwanted/unserviceable ammunition items due to the Military Munitions Rule, be sure that your procedures are consistent with the instructions from the appropriate NICP as well as those of the state or U.S. territory in which you are located. Destruction (after authorization) is usually accomplished by burning, if allowed by local environmental quality rules.

CHAPTER 3

MANAGING YOUR LOCAL STABILITY PROGRAM

When used in conjunction with published references and direction from IOC, the guidance which follows will help you create a well managed Propellant Stability Program which will assure the safety of your propellant stocks.

3-1. SPP SAMPLE TEST RESULTS

Test results will usually be submitted by the IOC to individual installations for the specific samples prepared and shipped by that installation. The DSR cards for those lots must be annotated with the test results.

a. SPP results for lots in Stability Categories “C” and “D” are sent from IOC via electronic message worldwide: Cat “C” for informational purposes and Cat “D” as a NAR suspension message.

b. Test results for other propellant lots in storage but not submitted by your installation for test (or in Cat “C” or “D”) will be included in the listing of all stockpile test results (titled “Propellant Stability Printout”) which is published and distributed annually each October by IOC. This all-inclusive list is of *critical importance* to the safe management of your propellant stocks.

3-2. PROPELLANT STABILITY PRINTOUT

The following actions should be taken by each installation upon receipt of the Propellant Stability Printout.

a. Within 5 (five) working days, the Printout should be examined and **EVERY** lot which is listed as Stability Category “C” or “D” should be highlighted and cross-checked against your installation's stock records to see if any of the lots listed are on hand at your location.

b. If there are no Category “C” or “D” lots found at your installation, then no other immediate action regarding the Printout is required.

c. If a *Stability Category “D”* lot is found in your local lot file:

(1) Check the DSR card to see if Stability Category “D” status has previously been identified.

(2) Confirm that action has been taken to destroy the lot ASAP *or* that destruction has already occurred.

(3) If action has *not* been taken or completed, or if the lot has *not* been previously identified as a Category "D" lot, *immediately* begin taking steps necessary to assure rapid destruction of this propellant.

d. If a *Stability Category "C"* lot is found in your local lot file:

(1) Check the DSR card to see if Stability Category "C" status has previously been identified.

(2) Confirm that proper actions IAW SB 742-1300-94-895 have been taken to obtain disposition from IOC; if Cat "C" propellants or propelling charges are not used or sold within 6 months, IOC will take action to destroy these stocks. *You* must identify these assets properly to assure this IOC disposition action occurs.

(3) If available, review previous test results on Category "C" material to check for possible rapid depletion of stabilizer. If a significant (greater than 25%) loss of stabilizer has occurred since the previous test, then *there may be some cause for greater concern* than that which would be afforded a lot with a more gradual deterioration rate. For example, the lot tested at 0.75% RES in 1993, but in 1998 the RES is 0.52%. While we do not advocate local trend analysis of propellant stability, such indication of rapid stabilizer loss warrants increased local concern.

e. *Stability Category "A" Lots:* The remainder of your propellant and propelling charge lots in storage can be checked against the Propellant Stability Printout at a time which is convenient with *your* schedule, because you have already confirmed the presence or absence of potentially hazardous lots. In the interest of timeliness, the review of propellant lots against the Printout should be completed within 60 days of Printout receipt.

NOTE: As stated in paragraph 3-2d.(3) above, if the new test result is *significantly* lower than the previous result (loss of 25% or more RES), it is possible that this particular lot is a "bad actor" and may require special attention from the SPP manager at IOC. You should identify these lots, with your concern, to the IOC as they are identified. *Always* insist upon a closing action from the IOC for your local documentation.

f. *Lots Not Found on the Printout:* If a bulk propellant or propelling charge lot (except Navy Materiel; see Chapt. 4) on hand at your installation *is not listed on the Printout*, it may not be included in the Propellant Stability Program as required. ***You must:***

(1) First check TB 9-1300-385 "Munitions Restricted or Suspended" to look for possible inclusion of the lot in PART 1 "Munitions Restricted or Suspended."

(2) If the lot does not appear in the TB or if further guidance is desired, call the Ammunition Surveillance Division at IOC for specific guidance. The IOC will probably do one of three things:

- provide you with current stability status of the lot
- make arrangements to have the lot tested
- direct that the lot be destroyed

g. Assure the DSR card for each propellant or propelling charge lot is properly annotated with the latest stabilizer test information.

(1) Keep the DSR remark as short as possible if lot remains in Stability Category “A”. If you still maintain a non-automated “hard card” DSR system, a minimal rubber stamp entry is sufficient, perhaps with the text:

“Propellant Stability Test performed <u>(date)</u>, <u>nn.n% RES</u>, Stab Cat <u>A</u>”.
(Underlined areas constitute blank lines for handwritten completion.)

(2) It is not necessary to fully annotate the results of the same test more than one time per DSR card. A proper DSR annotation for “repeat” test information could be a minimal entry consisting of remark date and a comment to the effect of **“Stab checked, Previous Entry Applies”** ...this will be sufficient to document your annual stability review.

(3) The entries may be as elaborate as you choose, but the information in 3-2g.(1) & (2) above is the minimum necessary. Entries for Stability Categories “C” and “D” will require considerably more detailed information.

3-3. DOCUMENTATION

a. Your review of installation stocks against the Printout must be documented. While the DSR entries consist of valid documentation, review of so many different records is impractical should you or someone else wish to double-check or confirm adequate review. Your working copy of the Printout should have some type of annotation or tick mark next to each lot entry reviewed which serves as confirmation that your complete review occurred.

(1) A *memorandum* should be prepared which attests that a complete and thorough review of the specific dated Propellant Stability Printout was conducted against all local assets in all owner accounts which are subject to the provisions of the Propellant Stability Program.

(2) This document should be *dated and signed by the QASAS conducting the review* and by the **QASAS in Charge**.

b. This memorandum, together with the DSR cards and your annotated working copy of the Printout, will serve as adequate assurance to anyone interested that you have taken all steps necessary to assure maximum safety of your installation's propellant stocks.

CHAPTER 4

NAVY GUN PROPELLANT SAFETY SURVEILLANCE

4-1. BACKGROUND.

Note: SW020-AE-SAF-010, Technical Manual "Safety Surveillance of Navy Gun Propellant", Policy and Procedures, 31 August 1996, is the best source for detailed information beyond the scope of this chapter.

a. The history of the Navy propellant surveillance program is very similar to that of the Army. Established at Indian Head, Maryland during the immediate post-World War I period, the Navy program was physically and technically a virtual twin of the Army program, which was begun just months later than that of the Navy in the year 1921. The oldest physical remains of both program's early days, the large, circular propellant heat chambers, appear to be built from the same design, during the same time period (1940-1941). Neither set of chambers at Indian Head nor at Picatinny are the "original" 1920's-vintage structures, which were based on steam heated chambers which proved to be insufficiently reliable.

b. Autoignition of propellant in the powder magazines aboard ship has caused the loss of many warships from the navies of various nations, most losses having occured in the first few decades of the 20th century. The risk of unstable propellant aboard ship was so great that, even after more effective stabilizers were introduced during the second decade of this century, close monitoring of all the fleet stocks was considered essential. In fact, prior to 1963, each activity and ship had its own testing oven and was required to run a 65.5^{0}C surveillance test for 60 days each year on every lot of propellant in stock. Propellants in many configurations which would be considered safe for use by the Army (such as propellant loaded into fixed rounds) were and are routinely condemned and destroyed by the Navy as too hazardous to be aboard ship, where even a minor deflagration can cost the lives of the sailors and marines aboard, such as that which occurred in the powder magazine of the USS KEARSARGE, killing 10 sailors.

c. Information necessary to assure the safety of Navy propellant stocks (and the vessels upon which they are stored) is provided to the fleet as well as storage installations (Navy coastals and SMCA locations) through the monitoring and testing of all existing Navy propellants. The Navy Gun Propellant Safety Surveillance program produces this information through its two programs, the **Master Sample Program** and the **Fleet Return Program.**

4-2. MASTER SAMPLE PROGRAM.

a. For the purposes of this Pamphlet, it is sufficient to say that the Master Sample Program is the same as the Army Master Propellant Program prior to the adoption of the Predictive Aging Test. Test procedures for the 65.5^{0}C test and minimum days to fume time are identical or virtually identical. The following are the most significant differences in the Navy Program vs Army:

(1) The term **“propellant index”** is used by the Navy *instead of* **“propellant lot”**. Do not be confused by the use of “index” when refering to Navy propellants; each index is a unique number which applies to only one lot of propellant. Use it as you would a lot number.

(2) The Navy maintains the 65.5^{0}C Accelerated Aging Test for most Navy propellants in a variety of configurations, and affixes the same *sentence* (disposition) for failed indices or lots which are loaded into fixed rounds as for bulk pack or separate loading propelling charges. Triple-base propellants are tested for stabilizer determination in lieu of the AAT. Other propellants which are *not* routinely included in the AAT are those propellants used for any calibers below 20mm, as well as some 20mm, 25mm, 30mm, and some Navy-owned ammunition that is designed and used by the Army (and included in the Army MPP)

(a) It has been demonstrated theoretically that unstable propellant in cartridge cases with a d*iameter as small as 10mm are capable of autoignition!* Aboard ship, any possibility of a magazine fire or explosion is an unacceptable risk.

(b) For example, if a lot of propellant fails the fume test (fumes in less than 30 days) but is loaded into Army 20mm rounds, the Army will take no action against these fixed round assets. If the propellant is loaded into Navy 20mm rounds, the fixed round lots into which that propellant is loaded will either be ordered destroyed by the Navy, or a retest on propellant extracted from fleet stocks may be ordered to assure that needed assets are not destroyed prematurely.

(3) The Navy maintains detailed records for each lot or index of propellant produced by or for them which identifies the final end item into which the propellant has been loaded (with the inevitable instances of information voids). The Navy is usually able to identify where their unstable propellant is located and into which end item lot it is loaded. Of course, accountability and/or inventory errors do occur, which makes the system less than 100% reliable.

b. The Navy conducts the Master Sample Program in relative anonymity, much like the Army MPP. Again like the Army, the results and records of the Master Sample Program are not disseminated to individual storage installations or the fleet, but rather are used by the chemists and technicians at Naval Surface Warfare Center, Indian Head, Maryland (IHDIV).

4-3. FLEET RETURN PROGRAM

a. While similar to the Stockpile Propellant Program in that “fielded” stocks are actually tested in addition to Master Samples, the Fleet Return Program is not nearly so extensive in operation as is the SPP. Like the SPP, individual samples are tested for remaining effective stabilizer using High Performance Liquid Chromatograph testing which is comparable to that at Picatinny Arsenal.

(1) Indian Head has been conducting an increasingly greater number of the stabilizer tests for this program using a mobile laboratory facility in conjunction with the MAERU team.

The mobile lab (a modified MILVAN) produces valid results quickly on-site, reducing the time from initial sampling to test result from several weeks to a few days.

(2) Less reliance is placed on the Fleet Return Program by the Navy than that which the Army places upon the SPP. To the Navy, this program is an adjunct to the Master Sample Program, which has amassed an impressive record in allowing the Navy to avoid any autoignition of propellant in a ship's magazine.

b. The likelihood of being called upon to prepare samples for the Fleet Return Program at the present time is not great. This program may grow, but the limited scope of the program today makes the likelihood of interaction small.

4-4. ADMINISTRATION OF NAVY PROPELLANTS

a. It may seem inconsistent that the requirement to maintain, at the installation level, known stability information does not apply toward Navy-tested propellants. Although the Navy's propellant stability management system is quite different from that of the Army, it *is* a system that works.

b. Because of their low reliance on testing which provides "percent stabilizer" for individual lots, the Navy does not routinely assign "Stability Categories" to their propellants. Don't be looking for Navy propellants on the IOC "Propellant Stability Printout"; you'll find them there on an exception basis only.

c. Be assured that the Navy, through its Gun Propellant Safety Surveillance organization at NSWC, Indian Head (IHDIV), continues to apply effective safety surveillance on its propellant assets. When an index is found to be unstable or nearing the end of its storage life, the Navy's action is very much like that of the Army.

(1) IHDIV will provides recommendations for ammunition reclassification to the Program Managers of the the various Naval ammunition programs (NAVSEA, NAVAIR & USMC). The appropriate Program Manager then makes a reclassification decision and directs the Naval Ordnance Center, Inventory Management and Systems Division (NOC/IMSD) Mechanicsburg, PA to issue a Notice of Ammunition Reclassification (NAR) for the affected index and/or complete round lots into which the propellant is loaded. You must treat this sentencing to destroy these stocks as seriously as you would an Army NAR which orders immediate destruction of Army bulk or bag charge propellant.

(2) The NAR information will be included in the next version of TWO 24-AA-ORD-010, "Ammunition Unserviceable, Suspended and Limited Use", the Navy's suspension and restriction manual. The propellant suspension information will remain a part of the publication for several years, until the Navy is confident that no traces of the propellant remain.

4-5 DOCUMENTATION OF STABILITY LEVELS

Actual annotation of individual stabilizer levels for Navy propellant is fairly simple for the storing installation: *it isn't done*. The Navy system forces you to assume that, unless you receive notice to the contrary, the propellant lot or index is stable. There is no NSWC-Indian Head equivalent to the IOC Propellant Stability Printout. Although this system is simpler than that of the Army, it lacks the installation-level safeguards which may be more likely to assure that unstable propellant is identified and removed from storage.

a. When shipping Navy propellants, it is very important to check the TWO/suspense manual, since this will be your only source to guard against shipping unstable propellant (no DSR card annotation).

b. You should conduct an *annual review* of all Navy propellant stocks on hand (includes SMCA stocks which are under the Navy propellant program) against the TWO/suspense manual and unincorporated NARs as a “reverse” means of assuring the stability of Navy propellants.

c. **DOCUMENT** your review of Navy owned/Navy tested stocks by listing each lot reviewed and attesting that lots so listed were not found in the TWO or NAR. This document should be dated and signed by the QASAS conducting the review and by the QASAS in Charge.

CHAPTER 5

PROPELLANT REASSESSMENT PROGRAM

5-1. PROGRAM DEFINITION AND APPLICATION

a. The Propellant Reassessment Program is defined by SB 742-1300-94-895 as a program which "involves the test and evaluation of stored propellant to determine functional serviceablity prior to loading into a major item." Because most installations store little if any of the propellants which are subject to the Program, Surveillance personnel occasionally forget to apply the special provisions of this program to the limited propellant items the Program affects.

b. The Program applies to Army-owned stocks of bulk propellant and to finished but unassembled component propelling charges (such as charges for mortar and semi-fixed howitzer ammunition).

c. Prior to becoming a part of a major end item, the Army wishes to be certain the propellant meets functional performance requirements in order to avoid the possible performance failure of the complete round lot of which it will become a part. The reassessment test determines functional suitability quickly and inexpensively.

d. Propellants which are subject to reassessment testing are also included in the Propellant Stability Program and are cyclically sampled for stabilizer analysis through stockpile testing.

-- NOTE --

The stability test sometimes misleads installation personnel who forget that stability tests and reassessment tests are conducted for two different purposes and are not interchangeable.

5-2. PROPELLANT REASSESSMENT TESTS:

a. Are conducted only by request of IOC based upon requirements for future LAP or maintenance projects.

b. Consist of a variety of laboratory tests and may include a functional firing test at a proving ground.

c. Result in approval or denial of LOADING AUTHORIZATION which is valid for a finite period of time, normally two or five years.

5-3. LOADING AUTHORIZATION

a. As documented by IOC Form 210-R "Propellant Acceptance Sheet," Loading Authorization is the key element and controlling factor in the Reassessment Program. Only with valid loading authorization may bulk propellant or component charges be assembled to complete round configuration.

b. The loading authorization affects the *Condition Code* of each lot as follows:

(1) *With* a current, valid loading authorization, the condition code of the propellant lot should be based upon results of visual inspection.

(2) When the lot has an **EXPIRED** or **UNKNOWN** loading authorization, the lot must be placed into **CC-D**, unless visual inspection warrants an unserviceable condition code.

5-4. DETERMINING NEED FOR LOADING AUTHORITY (YES or NO)

a. **NO**. Separate loading propelling charges (FSC 1320) are finished, complete end items in themselves and therefore **DO NOT** require further loading authority prior to use.

b. **NO**. Propellant which is loaded into complete rounds (such as propellant loaded into 120mm tank ammunition or *assembled* to mortar rounds) requires no further validation prior to issue or use.

c. **YES**. Loading Authority prior to use *is required* for *bulk propellant* and *component propelling charges* in FSCs **1310, 1315** and **1376**.

5-5. CONDITION CODES

Be alert and suspicious of Condition Codes assigned to propellant lots which are subject to the Reassessment Program.

a. Condition Code "D" for this material means that the Loading Authorization, as indicated on the IOC Form 210-R, has expired.

b. Any other *serviceable* Condition Code indicates that the lot *is currently authorized* for loading and use.

c. Failure to properly match the condition code with current load authority status can mislead ammunition planners when they are projecting stored assets for use.

5-6. STEPS for ISSUE or USE

a. **Receipt of Materiel Release Order from NICP**. If the item requested is propellant or a propelling charge, check first to see if the item is subject to the Propellant Reassessment Program. If the answer is yes, there is a good possibility that you will have already pre-arranged the MRO through a telephonic query from the NICP; you will have been expecting this MRO. Whether pre-arranged or not, *first* confirm upon MRO receipt that the lot requested is subject to the Program and is actually on hand in the requested condition code at your installation.

b. **Review DSR file**. The DSR card will indicate the loading authority expiration date. This in itself is not sufficient to allow issue. You must additionally have on file (with the DSR card if hard copy system is still in use) a copy of the IOC Form 210-R (Propellant Acceptance Sheet) which is the authenticating document for loading authority.

(1) *Assure* lot has current Cyclic inspection to meet shipping or use requirements.

(2) *Review* date of loading authority on IOC Form 210-R. Loading Authority must be valid for a length of time sufficient to meet the lot's intended purpose.

-- For example, if only seven months remain on the loading authorization and you believe the item will not reach its intended destination in time for use, then you must coordinate with the appropriate Item Manager at IOC or with the Ammunition Surveillance Division at IOC (who will in turn coordinate with the item manager).

(3) *Locally validate* loading authority expiration date on the IOC Form 210-R. On occasion, incorrect dates are annotated on the forms, or they are not specific as to level of pack (which affects expiration date). Remember that loading authority **NEVER** exceeds **FIVE YEARS** from date of original assessment or reassessment and, if the propellant is composition type M5, M10, or M26-series, the time limit never exceeds **TWO YEARS**.

(a) Lots stored in metal containers (cans or drums) or in metal lined wood containers (Level A pack) are authorized for loading for **FIVE YEARS** from date of test. (Except for propellants noted in para 5-6b(3) above)

(b) Lots stored in fiber drums (Level C pack), regardless of propellant composition, are authorized for loading for **TWO YEARS** from date of test.

(c) Your validation will consist of running a “sanity check” against the assigned expiration date (i.e., a date greater than five years from assessment, or one which doesn't meet time standards in (a) and (b) above).

(4) **All OCONUS shipment** of bulk propellant or component charges **MUST** be cleared through IOC Ammunition Surveillance Division prior to release for shipment.

(5) Should loading authority for the lot be expired or have insufficient time remaining to meet user requirements, place lot into the appropriate condition code (CC-D if expired loading authority) and contact IOC Ammunition Surveillance Division for instruction.

(6) Processing for shipment, after the above requirements have been met, *can now continue* as per any “normal” item shipment.

5-7. TEST INITIATION

Reassessment test will *always* be initiated by IOC, not the storing installation. It is very important that bulk propellant and component charges for which loading authorizations have expired be identified by the proper condition code (CC-D) and informative Defect Code in your Standard Depot System (SDS) input. Whenever a lot is selected for reassessment test, the Ammunition Surveillance Division at IOC will provide you complete instructions, to include sample selection, packing/marking, and shipping instructions.

5-8 REVIEW OF RECORDS

a. At least *once every two years* the DSR and SDS (or other automated format) records for all bulk propellant and component charges should be reviewed. You may wish to do it annually during reconciliation with the propellant stability listing.

(1) Confirm that the assigned condition codes match the load authority status of each lot.

(2) Confirm that the most recent copy of the IOC Form 210-R, Propellant Acceptance Sheet, is available and on file. If it is not, request a copy from IOC, Ammunition Surveillance Division.

(3) Assure the result of the most recent propellant stability test is annotated. If any of this material is in a Stability Category other than “A”, it will probably not be considered for use in loading. IOC should be queried for possible disposal action.

b. The date for loading authorization may be tracked on SDS by using the Shelf Life Code or Date of Next Inspection block to automatically prompt you when it expires. If this method is used, be sure it is documented in your local propellant procedures.

CHAPTER 6

GENERAL PROPELLANT MANAGEMENT

6-1. PROPELLANT TYPES OF GREATEST CONCERN

a. Some propellant types are more likely than others to become unstable during their expected normal storage life. Propellant formulations which historically have proven to be the most dangerous due to instability are types M10 and various versions of IMR powders. This does *not* mean that little concern should be shown for other propellant types. It *does* mean that both M10 and IMR powders have repeatedly proven themselves to be "bad actors" and have self-ignited on multiple occasions at a variety of storage locations. Pay particular attention to these types, particularly when stored in bulk pack configuration; **NEVER** allow them to be retained at your installation without a current, valid stability test. Since test intervals are generally undefined, proper stock retention may require the judgement of the QASAS in Charge.

b. *Single Base Propellants.* Formulations M10 and IMR are the single base propellants which are known to exhibit the greatest depletion of stabilizer (DPA for these and most single-base types). While not commonly stored in bulk configuration away from a LAP plant, they are still occasionally found in storage at non-manufacturing facilities, and they remain the most likely types to ever reach Stability Category "D". (Remember that Navy propellants also degrade, but the Navy generally does not assign Stability Categories; See NAVY Chapter 4).

c. Bulk storage or bulk-packed component storage of these items are of particular concern. Inspect the condition of the packaging for these items to be certain of package integrity and that they have not been exposed to moisture. Both these conditions may lead to rapid degradation of the propellant. Such conditions should prompt a request for testing the stability of such propellants.

6-2. OTHER PROPELLANTS AND PROPELLING CHARGES

a. As a general rule, single base propellant types M6 and M1 will exhibit similar aging profiles. The Army continues to maintain a large volume of aged M6 propellant which results in many more lots of M6 with lower levels of stability.

b. *Propelling Charges.* Most of the propellant lots which installations are required to monitor are assembled to separate loading propelling charges. Most propelling charges consist of M1 or M6 single base propellant, although triple base (such as M30) is common in some charges. Be sure to determine if the charge is of single or dual granulation. Check the ADC, too!

c. *Mortar Propellants.* When reviewing ammunition lot files, don't fail to look closely at FSCs 1310 and 1315 for bulk packaged mortar propellants.

(1) Mortar propellants (usually double base) are normally found already assembled to complete rounds and *WHEN SO CONFIGURED* require no special concern for stability.

(2) When packaged in bulk, mortar component charges require the same stability monitoring as do separate loading charges or bulk propellants.

d. Bulk packaged artillery component charges, such as the M67 charge for 105mm semi-fixed rounds (FSC 1315), also require stability monitoring.

6-3. RELEASE OF PROPELLANT FOR SHIPMENT

Propellant in bulk or that which is loaded/prepared into any configuration which makes it subject to the requirements of the Propellant Stability Program (propelling charges, component charges, bulk increments, etc.) *must* be verified with its current safe stability level prior to release for shipment beyond your installation boundary.

a. *Any* exceptions to the above policy must be authorized in writing from the Ammunition Surveillance Division, IOC.

b. Exceptions may include very low NC content propellants such as LOVA, or other composite types.

6-4. PROPELLANT GENERATION-DEMILITARIZATION

a. Generation of propellant as a result of demilitarization operations requires careful planning and close monitoring.

b. Propellant which has been uploaded in fixed rounds for many years may not have been retained in the Master Propellant Program, and it is highly unlikely to have had stockpile samples drawn for test.

c. Chances are good that the propellant to be generated from demil will have an absolutely *unknown stabilizer content*.

c. Within the IOC, the Commanding General's Policy Memo #41 (19 June 1998) explains the "Demilitarization Priorities for Excess and Obsolete Conventional Ammunition." Figure 1 graphically explains the decisions which must be made regarding propellant generation in order to comply with that policy. It is highly recommended that the Figure 1 Decision Chart be used at Non-IOC locations as well.

PROPELLANT DOWNLOAD DECISION CHART

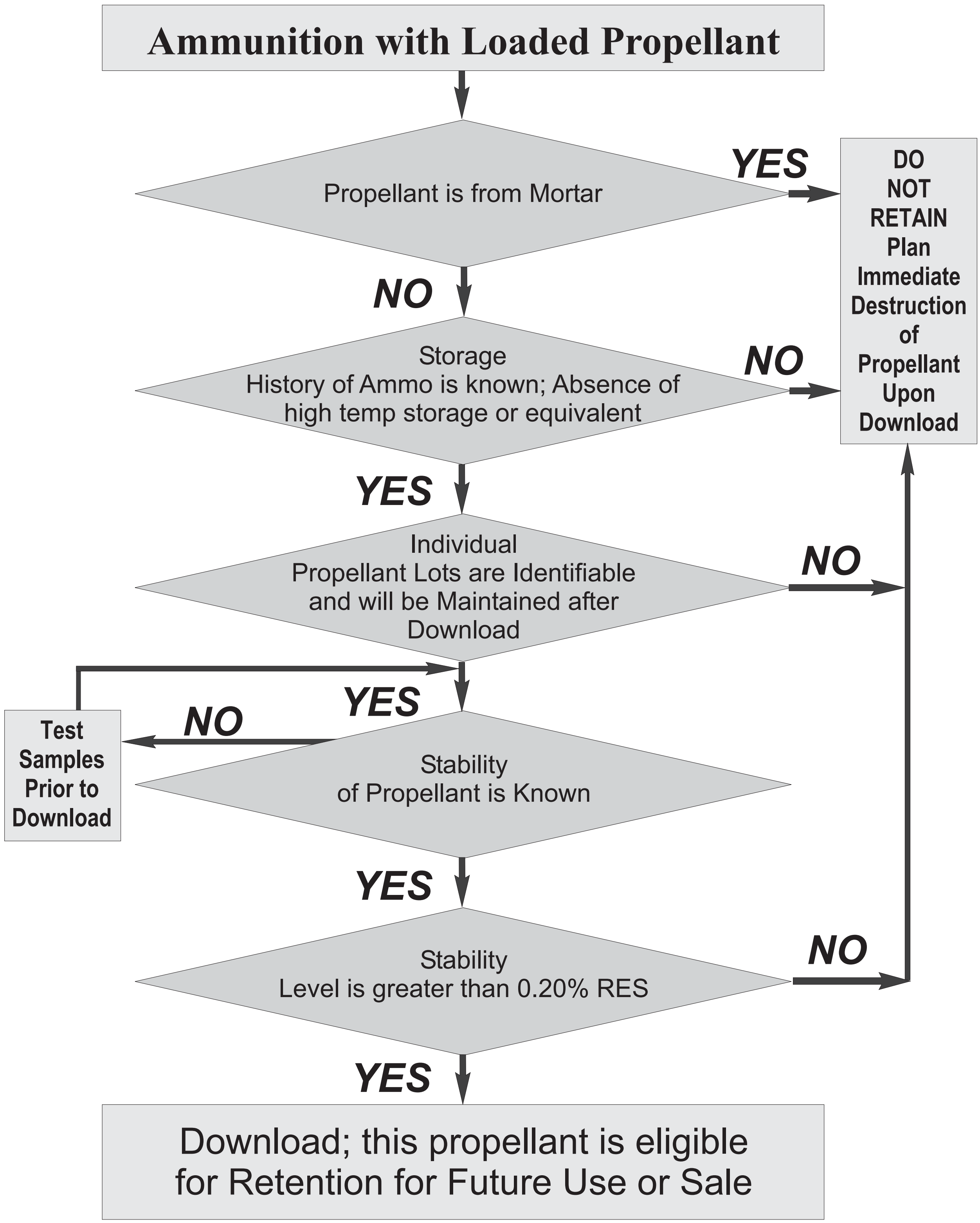

Figure 1

6-5. DEMILITARIZATION PLANNING ACTIONS.

a. Recommended actions prior to the start of any demil operation which results in the generation of propellant include:

(1) Review DSR cards of complete round lots to determine the propellant type, age, and lot number. Check the ADC to verify information and to ascertain if bag charges are/are not dual granulation.

(2) Compare lot numbers with Propellant Stability Printout. If listed, take further action regarding lot retention based on known stability. If not listed in Printout (which is probably the case), determine disposition of generated propellant in advance. The likely planned action for the propellant will be to destroy locally on a regular (daily, weekly, etc.) basis until completion of demil operation.

(a) If propellant stability cannot be determined prior to operation <u>and</u> propellant is to be destroyed locally as it is generated, assure the destruction takes place within 60 days of collection from breakdown of complete rounds.

(b) If propellant stability cannot be determined prior to operation and propellant is to be retained for greater than 60 days for <u>any reason</u> (reuse, nitrocellulose extraction, shipment to another location for destruction, destruction delay, etc.), a request for Stability Test must be made to IOC, Ammunition Surveillance Division prior to start of operation.

-- <u>WARNING</u> --

> Remember to take special care if generated propellant is of types <u>M10</u> or <u>IMR</u>. These propellants have been known to self ignite soon after reconstitution into bulk pack configuration.

b. *Funding* to pay for the costs associated with propellant stability management for demilitarization operations should be derived from the demil job itself. Ammunition Surveillance personnel must assure that these requirements and costs are included in installation planning for all demil operations which result in the generation of propellant.

6-6. SALE OF PROPELLANT TO COMMERCIAL VENDOR

a. Propellant may not be released from government custody unless stability level is known to be be safe for continued storage or use (Stability Categories A and C).

(1) If original lot or index numbers are not known, propellant cannot be sold or shipped because stability level cannot be verified. Lot integrity must be maintained for propellant which leaves government custody.

(2) New developments regarding the reuse and reprocessing of propellant may result in a *special situation* which will require specific guidance from IOC or higher headquarters. For example, a *special situation* may exist if propellant of unverifiable stability level is to be processed by a commercial vendor within the boundaries of the propellant's current government storage area.

b. As a rule of thumb, single and double base propellants should have been tested for stability within one year of sale or release to commercial vendor. A period of two or three years is sufficient for triple base and composite propellants. If in doubt, the suitability of most recent test will be determined by the Propellant Stability Program manager at IOC.

APPENDIX A

ABBREVIATIONS/ACRONYMS

AAP	Army Ammunition Plant
AAT	Accelerated Age Test
AMC	U.S. Army Materiel Command
ARDEC	Armament Research and Development Center (Picatinny Arsenal)
ASRP	Ammunition Stockpile Reliability Program
CC	Condition code
CONUS	Continental United States
DPA	Diphenylamine
DSR	Depot Surveillance Record
EC	Ethyl Centralite
FSC	Federal Supply Class
IOC	Industrial Operations Command
IMR	Improved Machine Rifle
LOVA	Low Vulnerability Ammunition
LRTAO	Logistics Review and Technical Assistance Office
MAERU	Mobile Ammunition Evaluation and Renovation Unit
MPP	Master Propellant Program
MRO	Materiel Release Order
NAR	Notice of Ammunition Reclassification
NC	Nitrocellulose
NG	Nitroglycerin
NQ	Nitroguanidine
NICP	National Inventory Control Point
NSWC/IH	Naval Surface Warfare Center, Indian Head
OCONUS	Outside Continental United States
PAS	Propellant Acceptance Sheet
PI	Periodic Inspection
PRP	Propellant Reassessment Program
PSP	Propellant Stability Program
QASAS	Quality Assurance Specialist (Ammunition Surveillance)
RES	Remaining Effective Stabilizer
SIP	Safe Interval Prediction
SMCA	Single Manager for Conventional Ammunition
SPP	Stockpile Propellant Program
TB	Technical Bulletin
TM	Technical Manual
USADAC	U.S. Army Defense Ammunition Center

APPENDIX B

RULES FOR PROPELLANT MANAGEMENT

1. SPECIAL WARNINGS

a. Be constantly aware that PROPELLANT MAY BE THE MOST DANGEROUS COMMODITY on your installation.

b. Carefully monitor the status of bulk pack quantities of M10 propellant and IMR powder at all times. Assure tests are timely and rate of deterioration is not too rapid. When in doubt, call IOC.

c. Require that stabilizer data be maintained for ALL propellant (except Navy), even that (ESPECIALLY that) belonging to various 11-series account holders. ALL must be included in the Propellant Stability Program.

d. Remember that Navy propellant is monitored for stability but uses a different reporting system than the Army. Navy Propellant indices should be checked against the Navy Suspense and Restriction manual and latest NARs.

e. During Magazine Inspections, be on the lookout for unreported stacks of bulk propellant or propelling charges. Be particularly cautious of RDT&E stocks and other "Special Purpose" accounts.

f. Prior to release of any propellant or propelling charge lot for shipment, confirm current stability level

2. LOT IDENTIFICATION

a. Identify ALL propellant stocks on hand at the installation, regardless of owner.

b. Request demil authorization for lots "UNKNOWN" and "NONE". These lots represent a potential safety hazard since stabilizer levels cannot be determined. There are NO stockpile requirements for these lots.

c. "LOT MIXED" as an identifier for propellant or propelling charges is a potentially unsafe practice and is *prohibited* from use.

d. Lot numbers are prone to transcription errors; information on Ammunition Data Cards is occasionally incorrect. *Assure* that any lot which lacks stability information is properly researched for correct identification; the container or charge bag is usually marked with the *correct* lot number.

3. PROPELLANT STABILITY PRINTOUT

a. Upon receipt of the “Propellant Stability Printout” from IOC, check ALL Stability Category “C” and “D” lots against your propellant stock records.

b. Assure all propellant and propelling charge lots have known stability levels, and that they are annotated on the DSR cards.

c. Maintain sufficient documentation to verify that all required stability reviews and annotations have been completed.

4. REASSESSMENT/LOADING AUTHORIZATION

a. Remember to differentiate between stability testing and reassessment testing. Stability Category “A” propellant can still be Condition Code “D” requiring reassessment.

b. Place into Condition Code “D” those bulk propellants and component charges for which the Loading Authorization has expired (but are otherwise serviceable).

c. If unserviceable for visual/physical reasons, place propellant and component charges into the appropriate unserviceable condition code REGARDLESS of loading authority date. If loading authority has expired and lot is in unserviceable code, assure defect code is included to indicate expired load authority.

d. Request a copy of the latest PAS (IOC Form 210-R) from IOC, Ammunition Surveillance Division, if unavailable at your installation.

e. When shipping bulk propellant or component charges, be sure to include the Propellant Acceptance Sheet along with the DSR card.

5. DEMILITARIZATION

a. Determine stabilizer level of lots to be generated prior to demil or teardown operation.

b. Maintain lot identity for propellant generated from fixed rounds.

c. DESTROY propellant generated in bulk from demil operations as quickly as possible (within 60 days), unless stability is known and at a safe level.

APPENDIX C

PROPELLANTS & CHARGES IN THE SPP

The following list contains identification of most of the bulk propellants, separate loading propelling charges, component charges, and incidental propellant-bearing components which may be in the SMCA inventory that are subject to the rules and direction of the Stockpile Propellant Program.

NSN	DODIC	NOMENCLATURE
1145-00-103-8071	DX23	CHARGE,PROPELLING,155MM
1145-00-140-6685	DX28	CHARGE,PROPELLING,155MM
1145-00-140-6779	DX29	CHARGE, PROPELLING, 155MM
1310-00-028-4981	B622	CHARGE, PROP. INCR , M3A1 BAG (M8PROP)F/60MM
1310-00-826-5395	BX14	CHARGE, PROPELLANT INCR(M8 PROP)M182F/60MM
1310-00-837-2906		PROPELLANT INCREMENT
1310-00-854-6648	BX08	CHARGE,PROP INCR M181 F/60MM M302E1
1310-01-050-8896	ZZDT	CHARGE, PROPELLING, M10 PROP F/60MM M204
1315-00-028-4982	C240	CHG, PROP INCR, M1A1 FULL(BAG 6) F/81MM M1 & M29
1315-00-028-4983	C239	CHG, PROP INCR, M2A1 FULL (BAG 4) F/81MM M301A2
1315-00-028-5009	C709	CHARGE, PROPELLING, 4.2 INCH 25.5 RINGS/ CHARGE (M6)
1315-00-038-4983	C239	CHARGE, PROPELLANT INCREMENT, M2A1 & HOLDER, M3
1315-00-126-9035		PROPELLANT POWDER, M6 F/90MM CTG, M82
1315-00-128-4952	C241	PROPELLANT INCREMENT, M5 F/81MM
1315-00-141-0237	C773	CHG, PROP, 120MM, M45, FULL NFL (BAGGED 6) F/GUN M58
1315-00-152-9912	C437	CHARGE, PROPELLING, 105MM M121 (XM121) ZONED
1315-00-220-2362		CHARGE, PROPELLING, 81MM
1315-00-351-7910	ZARG	HALF INCR,M8 PROP F/PROP CHG M36/M36A1 F/4.2 INCH
1315-00-351-7911		FIVE INCR BUNDLE F/PROP CHG M36/36A1A1 F/4.2 INCH
1315-00-351-7912		INCREMENT, SINGLE F/CHG, PROP. M36/36A1 F/4.2 INCH
1315-00-351-7914	CX30	BAG LOADING ASSY 5 INCR. BAG F/CHG PROP M36 F/4.2 INCH
1315-00-370-3548	C021	INCREMENT A, M9 PROP, F/ CHG PROP M90A1 F/81MM
1315-00-378-9841	C022	INCREMENT B, M9 PROP, F/ CHG PROP M90A1 F/81MM
1315-00-425-0725	C020	CHARGE, PROPELLING, M185, M9 PROP F/81MM
1315-00-425-6040	C873	CHARGE PROPELLING, M36A1, M8 PROP, F/4.2 IN
1315-00-431-3444	C872	CHARGE, PROPELLING, M82 NFL F/90MM CTG
1315-00-434-5508	C279	CHARGE, PROPELLING, M90A1 FULL F/81MM
1315-00-821-6665	CX69	HALF INCR F/PROP CHG, M36/M36A1 F/4.2 INCH
1315-00-821-6685	CX30	BAG LOADING ASSY. M9 PROP F/CHG PROP M36A1
1315-00-825-1384	C436	CHARGE, PROPELLING,M67, WHITE BAG F/105MM
1315-00-825-1401	C434	CHARGE, PROPELLING,M1, FULL, WHITE BAG F/105MM
1315-00-826-5393	CX02	PROP FIVE INCR BUNDLE F/PROP CHG M36/ M36A1 F/4.2 INCH
1315-00-826-5401		INCREMENT, M1A1, M8 PROP F/81MM
1315-00-826-5404	C239	CHG PROP ,M2A2 FULL M2A1 INCR F/81MM
1315-00-826-5422		INCREMENT, CHARGE, PROPELLING, M36 SERIES
1315-00-828-7444	C873	CHG, PROP, M36A1, M8 PROP F/4.2 IN

NSN	DODIC	NOMENCLATURE
1315-00-828-7465	C435	CHARGE, PROPELLING, M6 WHITE BAG F/105MM
1315-00-837-3246		CHARGE, PROPELLING F/75MM
1315-00-854-6645	C019	CHARGE, PROPELLING, M5,M9 PROP F/81MM
1315-00-854-6646	CX47	CHARGE PROPELLING,M9 PROP F/81MM, M90 INCREMENT
1315-00-883-1472	CX46	CHARGE PROPELLING, M90, INCR A F/81MM
1315-00-965-0841	C239	CHARGE, PROPELLANT,M2A1 INCR, M8 PROP F/81MM
1315-00-A01-0740	C019	PROPELLANT INCREMENT M5 F/81MM
1315-00-D00-5278		PROPELLANT, M8, FRONT ASSEMBLY
1315-00-D00-8438		CHARGE, PROPELLING,105MM,PXR200
1315-00-D00-8589		BASE CHARGE ASSY, JA-2 PROP., 19 & 7 PERFORATION
1315-00-D00-8693		CHARGE, PROPELLING M230 F/120MM MORTAR
1315-00-D00-8733		CHARGE, PROPELLING F/120MM M57 WHITE BAG
1315-00-D00-8734		CHARGE, PROPELLING F/120MM M57 BLUE BAG
1315-00-D00-9891		CHARGE, PROPELLING, MODIFIED M230
1315-01-030-0442		PROPELLANT GRAIN, M5 FLAKE PROP,F/90MM
1315-01-050-8882	C043	CHARGE, PROPELLING M205, M10 PROP F/81MM
1315-01-050-8906		BAG LDNG ASSY, M9 PROP F/ PROPCHG M36A2 F/4.2 IN
1315-01-055-5519		CHARGE, PROPELLING F/90MM CTG M590
1315-01-055-8590	C716	CHARGE,PROPELLING,M36A2,M8 PROP F/81MM
1315-01-066-2790	C427	CHARGE, PROPELLING, M1 PROP, BAGGED,FULL, F/105MM
1315-01-122-8591		CHARGE PROPELLING,M1 PROP F/105MM
1315-01-223-7299		CHARGE PROPELLING F/120MM M830/831
1315-01-233-2316		CHARGE, PROPELLING, M30 PROP F/105MM
1315-01-237-9775	C436	CHARGE, PROPELLING, M67 F/105MM
1315-01-255-9037		PROPELLANT GRAIN F/105MM HERA XM912
1315-01-290-1597		CHARGE, PROPELLING, M219 F/CTG 81MM
1315-01-290-1598		CHARGE PROPELLING,M218 (M38 prop)F/81MM SMK M819
1315-01-329-2575	C044	CHARGE, PROPELLING, M220 F/81MM
1315-01-336-7185	C436	CHARGE, PROPELLING, M67 F/105MM
1315-01-337-8940	C436	CHARGE, PROPELLING, M67 F/105MM
1315-01-363-6509		CHARGE PROPELLING, W/REDUCER F/105MM CANNON
1315-01-413-9822	C436	CHARGE, PROPELLING, M67 F/105MM
1320-00-006-9654	D479	CHARGE, PROPELLING, M189 W/PRIMER F/152MM
1320-00-009-5316	D018	CHARGE ASSEMBLY,EXPULSION, M10 PROP F/155MM
1320-00-014-2451	D661	CHARGE, PROPELLING,XM188E3 F/ 8 IN 55 CAL
1320-00-028-4369	D480	CHARGE, PROPELLING,M19 W/O PRIMER F/155MM
1320-00-028-4371	D480	CHARGE, PROPELLING,M19 W/PRIMER F/155MM
1320-00-028-4374	D675	CHARGE, PROPELLING, M1 W/O PRIMER F/8 IN
1320-00-028-4375	D676	CHARGE, PROPELLING, M2,W/O PRIMER F/8 IN
1320-00-028-4378	D676	CHARGE, PROPELLING, 8 INCH M2, 2 INCR W/PRIM F/HOW
1320-00-028-4381	D715	CHARGE, PROPELLING, M43 W/PRIMER F/280MM
1320-00-028-4873	D540	CHARGE, PROPELLING, M3 W/PRIMER F/155MM
1320-00-028-4876	D540	CHARGE, PROPELLING, M3 W/O PRIMER F/155MM
1320-00-028-4877	D541	CHARGE, PROPELLING, M4 F/155MM

NSN	DODIC	NOMENCLATURE
1320-00-028-4878	D541	CHARGE, PROPELLING, M4A1 WB W/O PRIMER F/155MM
1320-00-028-4879	D541	CHARGE, PROPELLING, M4A1 W/PRIMER F/155MM
1320-00-070-4485	D662	CHARGE, PROPELLING, M188A1 WHITE BAG F/8 IN
1320-00-106-8549	D362	CHARGE, PROPELLING, XM199 F/175MM
1320-00-113-8006	D676	CHARGE, PROPELLING,M2, WB, W/O PRIMER F/8 IN
1320-00-143-6847	D533	CHARGE, PROPELLING, M119 , W/O PRIMER F/155MM
1320-00-182-3030	D361	CHARGE, PROPELLING, M86A2 W/PRIMER F/175MM
1320-00-308-5539	D676	CHARGE, PROPELLING, M2 F/8 IN
1320-00-308-5555	D676	CHARGE, PROPELLING, M2 F/8 IN
1320-00-451-4907	D536	CHARGE, PROPELLING, M124,M6 PROP, F/175MM
1320-00-542-0132	D675	CHARGE, PROPELLING, M1 W/PRIMER F/8 IN
1320-00-628-7741	D674	CHARGE, PROPELLING M80 F/8 IN
1320-00-767-9441	D534	CHARGE, PROPELLING, XM119 W/PRIMER F/155MM
1320-00-775-1533	D536	CHARGE, PROPELLING, M124 W/PRIMER F/175MM
1320-00-783-7980	D017	CHARGE ASSEMBLY, EXPULSION,M10 PROP F/8 IN
1320-00-892-4201	D361	CHARGE, PROPELLING, M86 W/PRIMER F/175MM
1320-00-926-3986	D361	CHARGE, PROPELLING, M86A2 W/PRIMER F/175MM
1320-00-935-1922	D540	CHARGE, PROPELLING, M3A1 W/O PRIMER F/155MM
1320-00-935-1923	D541	CHARGE, PROPELLING, M4A2 W/O PRIMER F/155MM
1320-00-995-8022	D537	CHARGE, PROPELLING, XM115 F/155MM
1320-00-D00-2569		CHARGE, PROPELLING, XM224 MOD REAR F/155MM
1320-00-D00-2570		CHARGE, PROPELLING, ,XM224 MOD FWD F/155MM
1320-00-D00-7858		CHARGE ASSEMBLY,EXPULSION,M10 PROP
1320-00-D00-7858		EXPULSION CHARGE ASSEMBLY
1320-00-D00-9441		EXPULSION CHARGE ASSEMBLY F/XM982
1320-00-D00-9876		CHARGE, PROPELLING, L6A1 W/O PRIMER F/155MM
1320-00-D01-0012		CHARGE, PROPELLING, XM232 W/XM231 CASE
1320-00-D01-0051		PROPELLANT GRAIN, AFT F/XM982
1320-00-D01-0063		EXPULSION CHARGE ASEMBLY
1320-00-X11-0326		CHARGE,PROPELLING, M203E2 F/155MM
1320-00-X11-0355		CHARGE, PROPELLING, XM216A F/155MM
1320-00-X11-0359		CHARGE, PROPELLING, XM216B F/155MM
1320-00-X11-0609		CHARGE, PROPELLING, XM224 BASE INC.F/ 155MM
1320-00-X11-0610		CHARGE, PROPELLING, XM224 FWD INC F/155MM
1320-00-X11-0718		CHARGE, PROPELLING, FH70, CHG 7 F/155MM
1320-01-014-2451	D661	CHARGE, PROPELLING, M188E3 FULL F/ 8 IN 55 CAL
1320-01-015-6243	D010	CHARGE ASSEMBLY, EXPULSION F/8 INCH PROJ XM172
1320-01-020-8938	D532	CHARGE, PROPELLING,M203 SERIES RB F/155MM
1320-01-033-9394	D532	CHARGE, PROPELLING, M203 W/O PRIMER F/155MM
1320-01-041-9890	D531	CHARGE, PROPELLING, XM201E5 F/155MM
1320-01-051-4132	D533	CHARGE, PROPELLING, M119A F/155MM
1320-01-052-1317	ZZKC	CHARGE ASSEMBLY, EXPULSION, M10 PROP, F/155MM
1320-01-054-5107		PROPELLANT GRAIN F/155MM RAP M549
1320-01-057-8440		PROPELLANT GRAIN, F/155MM M549

NSN	DODIC	NOMENCLATURE
1320-01-070-4485	D662	CHARGE PROPELLING, M188A1 WB W/O PRIMER F/ 8 IN
1320-01-070-4486	D662	CHARGE, PROPELLING, M188A1 WB W/O PRIMER F/8 IN
1320-01-077-1312		PROP GRAIN, XM650E5 F/HERA 8 IN M650 (1320-D624)
1320-01-093-6856	D533	CHARGE, PROPELLING, M119A2 W/O PRIMER F/155MM
1320-01-112-1624	D032	CHARGE ASSY, EXPULSION, M10 PROP F/155MM
1320-01-152-5613		CHARGE PROPELLING WB F/155MM
1320-01-164-3486	D030	CHARGE ASSY, EXPULSION, M10 PROP F/155MM PROJ.
1320-01-186-5653		PROP GRAIN F/FWD RKT MTR F/155MM M549A1 2CLASS
1320-01-186-6564		PROP GRAIN F/AFT RKT MTR F/155MM M549A1 2CLASS
1320-01-187-7651		PROP GRAIN F/FWD RKT MTR F/155MM M549A1 1CLASS
1320-01-187-7652		PROP GRAIN F/AFT RKT MTR F/155MM A549A1 1 CLASS
1320-01-202-3989	D532	CHARGE, PROPELLING,M203 SERIES, RB F/155MM
1320-01-202-8938	D532	CHARGE, PROPELLING, M203A1 F/155MM
1320-01-231-7231	D662	CHARGE, PROPELLING, M188A1 WB W/O PRIMER F/8 IN
1320-01-285-0134	D471	CHARGE, PROPELLING, XM216 F/155MM
1320-01-285-3066	D470	CHARGE, PROPELLING, XM215 F/155 MM
1320-01-285-6415	D472	CHARGE, PROPELLING, XM 216, INCR B F/155MM
1320-01-307-3952	D540	CHARGE, PROPELLING, M3A1 GB W/O PRIMER F/8 IN
1320-01-307-3953	D541	CHARGE, PROPELLING M4A2 WB W/O PRIMER F/155MM
1320-01-310-4857	D533	CHARGE, PROPELLING, M119A2 F/15MM
1320-01-312-9058		CHARGE PROPELLING,M119A1 F/155MM
1320-01-312-9059		CHARGE PROPELLING,M3A1 GB W/O PRIMER F/155MM
1320-01-317-2382		CHARGE PROPELLING,M4A2 W/O PRIMER F/155MM
1320-01-320-0966		CHARGE ASSEMBLY, EXPULSION, M10 PROP F/155MM
1320-01-334-9448		CHARGE ASSEMBLY, EXPULSION, M10 PROP F/155MM
1356-01-106-5985		PROPELLANT, INITIATING F/TORPEDO, MK48 MOD 0
1376-00-006-9652		PROPELLANT POWDER , M6 F/ 75MM
1376-00-006-9653		PROPELLANT POWDER, M6 F/105MM
1376-00-009-0041		PROPELLANT POWDER, M1,SP F/105MM, M67 PROP CHG
1376-00-009-0042		PROPELLANT POWDER, M1,MP F/105MM, M67 PROP CHG
1376-00-009-0043		PROPELLANT POWDER, M10,SP F/57MM WEB 0,025
1376-00-009-0044		PROPELLANT POWDER,M10,SP F/57MM
1376-00-009-0045		PROPELLANT POWDER,M30E1 F/155M PROP CHG XM123
1376-00-009-0046		PROPELLANT POWDER,M30A1, MP F/ 8 IN PROP CHG
1376-00-053-9367		PROPELLANT POWDER,M30 F/ 90MM CARTRIDGE M431
1376-00-053-9371		PROPELLANT, POWDER,M30 F/105MM M728E1
1376-00-068-5086		PROPELLANT POWDER, M30,MP F/105MM M392A2
1376-00-084-5010		BENITE POWDER, SMOKELESS
1376-00-126-9035		PROPELLANT POWDER, M6 F/CARTRIDGE 90MM
1376-00-279-8760		PROPELLANT POWDER, M6 F/90MM CARTRIDGE
1376-00-432-2101		PROPELLANT POWDER, M30 F/90MM CTG
1376-00-432-2191	XX10	PROPELLANT POWDER, M30 F/CTG 90MM M318/M353
1376-00-451-2881		PROPELLANT POWDER, M1 RECLMED F/155MMPROP CHG
1376-00-451-2882		PROPELLANT M2,MP, RECLAIMED F/165MM M123A1

NSN	DODIC	NOMENCLATURE
1376-00-451-2883		PROP POWDER M6,SP, RECLAIMED F/CTG 90MM
1376-00-451-4906		RECLAIMED PROPELLANT F/SMALL ARMS (IMR) (M1)
1376-00-451-4907		PROPELLANT POWDER, M6 F/175MM PROP CHG M12M4 GB
1376-00-476-9357		PROP POWDER,M10 F/57MM, 75MM AND 105MM RECLAIMED
1376-00-653-9822		PROPELLANT, BALLISTITE,BULK, N-1 SHEETS
1376-00-653-9825		PROPELLANT, BALLISTITE,BULK, N-5 SHEETS
1376-00-694-2017		PROPELLANT POWDER F/PISTOL P4768
1376-00-772-1370		PROPELLANT POWDER F/EXPL SCENT KIT,CANINE
1376-00-854-6659		PROPELLANT POWDER,M17, TYPE 2 F/90MM, M318A1
1376-00-854-6710	CX52	PROPELLANT POWDER,M26 F/CTG 106MM HEAT M344A1
1376-00-871-2829		PROPELLANT POWDER,M1,MP F/VARIOUS TYPES
1376-00-871-2889		PROPELLANT POWDER F/155MM M4A1
1376-00-937-3922		PROPELLANT POWDER, BENITE 9 IN. LENGTH
1376-00-937-3940		BENITE 10 IN. LENGTH F/PRIMER, M83
1376-00-937-3978		PROPELLANT POWDER BENITE STRANDS 11.437 IN LENGTH
1376-00-937-3995		BENITE 17 IN. LENGTH F/PRIMER, M80A1
1376-00-979-6091		PROP POWDER, PYROCELLULOSE, STANTON, STARTER
1376-00-979-6092		PROP POWDER, PYROCELLULOSE, STANTON, STARTER
1376-00-987-6802		PROPELLANT GRAIN, 10 IN. LENGTH
1376-01-030-0442		PROPELLANT,M5, SP,FLAKE, F/90MM CHG, M82
1376-01-048-9868		PROPELLANT POWDER,IMR 5010, F/ CTG CAL .50 BALL M33
1376-01-049-1448	C558	PROPELLANT POWDER, WC 846 F/7.62MM TRACER M62
1376-01-049-1449		PROPELLANT POWDER, WC846 F/7.62MM BALL M80
1376-01-049-1450		PROPELLANT POWDER, WC846 F/7.62MM MATCH M118
1376-01-049-1451		PROPELLANT POWDER, IMR 8028 F/5.56MM TR, M196
1376-01-049-1452		PROPELLANT POWDER, IMR 7383 F/50 CAL SP TR, M48A2
1376-01-049-1453		PROPELLANT POWDER,IMR 8097 F/7.62MM GRN RIFLE M64
1376-01-049-1454		PROPELLANT POWDER,IMR 5010 F/CTG, CAL 50 TR M17
1376-01-049-1455		PROPELLANT POWDER,IMR 4895 F/CTG, CAL 30 BALL, M2
1376-01-049-1456		PROPELLANT POWDER,IMR 4895 F/CTG, CAL 30 TR
1376-01-049-1457		PROPELLANT POWDER,IMR 4895 F/7.62MM MATCH, M118
1376-01-049-1458		PROPELLANT POWDER,HPC-4 F/7.62MM CTG GR RIFLE M64
1376-01-049-1459		PROPELLANT POWDER,HPC-8 F/7.62MM FRANG., M160
1376-01-049-1460		PROPELLANT POWDER,HPC-13 F/5.56MM BLANK, M200
1376-01-049-1461		PROPELLANT POWDER,SR4900 F/CTG CAL 30, BLNK M1909
1376-01-049-1462		PROPELLANT POWDER,SR 8231 F/CTG, 7.62MM BLNK, M82
1376-01-049-1463		PROPELLANT POWDER,CMR 100 F/CTG, CAL 30, BALL, M2
1376-01-049-1464		PROPELLANT POWDER,WC 820 F/CTG, CAL 30, BALL, M1
1376-01-049-1465		PROPELLANT POWDER,HPC-5 F/CTG, CAL 30, BALL, M1
1376-01-049-1466		PROPELLANT POWDER,HPC-2 F/7.62MM BLANK, M82
1376-01-049-1467		PROPELLANT POWDER,WC 818 F/7.62MM BLANK, M82
1376-01-049-1468		PROPELLANT POWDER,WC 852 F/CTG, CAL 30, BALL, M2
1376-01-049-1469		PROPELLANT POWDER, WC 870 F/CTG, 20MM
1376-01-050-7209		PROPELLANT POWDER,M26E1 F/152MM PROP CHG M189

NSN	DODIC	NOMENCLATURE
1376-01-053-0362		PROPELLANT POWDER,M6 TYPE1 F/105MM CTG M494
1376-01-053-9358		PROPELLANT POWDER, M1
1376-01-053-9359		PROPELLANT POWDER, M30, TYPE 1 F/105MM CTG
1376-01-053-9360		PROPELLANT POWDER, M1, TYPE 1 F/105MM CTG
1376-01-053-9362		PROPELLANT POWDER,M6, MP, TYPE 1 F/105MM CTG
1376-01-053-9363		PROPELLANT POWDER,M9 FLAKE F/105MM CTG
1376-01-053-9364		PROPELLANT POWDER,M9, FORM A F/4.2 IN PROP CHG
1376-01-053-9365		PROPELLANT POWDER,M9, FLAKE F/81MM INCR.M185
1376-01-053-9366		PROPELLANT POWDER,M9, FORM A F/4.2 IN PROP CHG
1376-01-053-9367		PROPELLANT POWDER,MIXTURE M30 F/CTG, 90MM
1376-01-053-9368		PROPELLANT POWDER, M5 MIXTURE, FORM A
1376-01-053-9369		PROPELLANT POWDER,M26 F/CTG 106MM RIFLE
1376-01-053-9370		PROPELLANT POWDER,M6,MP F/175MM M86 SERIES
1376-01-053-9371		PROPELLANT POWDER,M30 F/ 105MM
1376-01-053-9372		PROPELLANT POWDER, M6,MP F/155MM M119 SERIES
1376-01-053-9373		PROPELLANT POWDER,M9, FORM A F/40MM CTG
1376-01-053-9373		PROPELLANT POWDER,SHEET 33 IN LENGTH
1376-01-054-1577		PROPELLANT POWDER,M1MP F/155MM M4A2 WB
1376-01-054-5157		PROPELLANT POWDER,CR8325 F/20MM CTG, M139
1376-01-054-5158		PROPELLANT POWDER,WC875 F/20MM CTG M99A1
1376-01-054-5171		PROPELLANT POWDER,IMR4475 F/7.62MM, M60, HPT
1376-01-055-0993		PROPELLANT POWDER,HPC F/CAL 38 CTG,BALL
1376-01-055-0995		PROPELLANT POWDER F/7.62MM GRENADE CTG, M64
1376-01-055-0996		PROPELLANT POWDER F/CAL .30 M1909 BLANK
1376-01-055-0997		PROPELLANT POWDER,WC860 F/CAL 50 BALL M33/AP M2
1376-01-055-0998		PROPELLANT POWDER,WC844, F/5.56MM, M193 BALL
1376-01-055-0999		PROPELLANT POWDER,WC,F/7.62MM FRANGIBLE, M160
1376-01-055-1000		PROPELLANT POWDER,SR, F/7.62MM FRANGIBLE, M160
1376-01-055-1001		PROPELLANT POWDER,IMR, F/5.56MM HPT
1376-01-055-1551		PROPELLANT POWDER, M30A1, MP
1376-01-055-1555		PROPELLANT POWDER,M30A1,MP,F/105MM PROP CHG
1376-01-055-2772		PROPELLANT POWDER,WC844, F/5.56 BALL M196 TR
1376-01-055-2783		PROPELLANT POWDER,M6+2, MP F/GUN 76MM
1376-01-055-2784		PROPELLANT POWDER, NACO, F.5IN 54 CAL
1376-01-055-3436		PROPELLANT POWDER,M1 F/105MM M724A1
1376-01-055-3437		PROPELLANT POWDER,M30,MP, F/105MM M735, M392
1376-01-055-5971		PROPELLANT GRAIN, SHEET STOCK, 15 IN CARPET ROLLS
1376-01-055-8597		PROPELLANT POWDER,M1,SP F/8 INCH CHG, PROP M2
1376-01-055-8598		PROPELLANT POWDER,M10 FLAKE F/155MM & 8IN
1376-01-055-8599		PROPELLANT POWDER, M30A2, MP F/8 IN PROP CHG, M188
1376-01-055-9903		PROPELLANT POWDER, MIXTURE M5
1376-01-055-9904		PROPELLANT POWDER,M10 FLAKE F/81MM M205 INCR
1376-01-056-0768		PROPELLANT POWDER,M1 F/90MM M71
1376-01-056-2671		BENITE 14 IN. LEMGTH F/PRIMER XM120

NSN	DODIC	NOMENCLATURE
1376-01-058-1652		PROPPELLANT POWDER,IMR F/CAL 30 TR/7.62MM M118
1376-01-058-1653		PROPELLANT POWDER (WC) F/CAL .30 TR M27 CARBINE
1376-01-058-5086		PROPELLANT POWDER,M30
1376-01-059-4572		PROPELLANT POWDER M9 FLAKE F/81MM M90A1 A/B CHGS
1376-01-063-0140		PROPELLANT POWDER,M1,SP F/155MM M3A1
1376-01-064-7316		PROPELLANT POWDER,M6 PROP FORM C TYPE 1
1376-01-065-9849		PROPELLANT POWDER,M30,MP F/76MM CTG
1376-01-065-9850		PROPELLANT POWDER,M5 PROP F/90MM CTG M37E1/M371
1376-01-066-4179		PROPELLANT POWDER,M2 PROP
1376-01-066-4180		PROPELLANT POWDER,M30,MP F/105MM M735
1376-01-066-5003		PROPELLANT POWDER,IMR F/CAL .50 API-T, M20
1376-01-068-5086		PROPELLANT POWDER,M30,MP F/105MM M735
1376-01-068-5087		PROPELLANT POWDER,M1 COMP F/ 105MM M724E1
1376-01-073-7529		PROPELLANT POWDER,WC872 F/20MM BALL
1376-01-076-2607		PROPELLANT POWDER, M30A1,SP F/105MM M85,M121
1376-01-078-4062		PROPELLANT POWDER,M6, MP F/76MM M496 HEAT
1376-01-078-8199		PROPELLANT POWDER,WC 680 F/7.62MM BALL
1376-01-082-2105		PROPELLANT POWDER,M9 FLAKE F/81MM INCR M90/90A1
1376-01-084-4229		PROPELLANT POWDER,M30A1,MP F/155MM M203
1376-01-085-1882		PROPELLANT POWDER,M10FLAKE F/60MM M204 INCR
1376-01-085-7243		PROPELLANT POWDER,M2 F/40MM
1376-01-086-2973		PROPELLANT POWDER,M31A1,MP F/8 IN PRPCHG M188E1A1
1376-01-099-0236		PROPELLANT POWDER,M9 F/60MM IGNITION CTGS
1376-01-107-5378		PROPELLANT POWDER,M9 FLAKE F/60/81MM IGN CTG
1376-01-110-5580		PROPELLANT POWDER,M30A1 F/8 IN
1376-01-120-0956		PROPELLANT POWDER F/NAVAL GUNS ITYPE
1376-01-120-0957		PROPELLANT POWDER F/PROP CHG F/CANNON
1376-01-120-4100		PROPELLANT POWDER,M31 PROP F/120MM PROP CHG M45
1376-01-120-4560		PROPELLANT POWDER,IMR 4903 F/20MM CTG
1376-01-122-5289		PROPELLANT POWDER F/VARIOUS SOLID PRP RKT GRAINS
1376-01-123-5089		PROPELLANT POWDER,M17 F/CARTRIDGE, 90MM, M353
1376-01-125-5945		PROPELLANT POWDER,M30 PROP F/105MM
1376-01-125-5946		PROPELLANT POWDER,M30 F/105MM HEAT-T M456A2
1376-01-126-3602		PROPELLANT POWDER,BS NACO F/5 IN 38 PROP CHG
1376-01-126-5051		PROPELLANT POWDER F/NAVAL GRAINS
1376-01-126-8342		PROPELLANT POWDER,M10 FLAKE
1376-01-127-0728		PROPELLANT POWDER F/NAVAL GUNS
1376-01-127-5190		PROPELLANT POWDER SPD F/5 IN 38
1376-01-127-5191		PROPELLANT POWDER SPD F/5 IN 54
1376-01-127-5192		PROPELLANT POWDER SPD F/6 IN 47
1376-01-127-5193		PROPELLANT POWDER SPD F/16 IN 45
1376-01-127-5194		PROPELLANT POWDER,SPD,PYROCELLULOSE F/16 IN 50
1376-01-127-9539		PROPELLANT POWDER, SPDB F/3 IN 50
1376-01-127-9540		PROPELLANT POWDER,SPDB,PYROCELLULOSE F15 IN 38

NSN	DODIC	NOMENCLATURE
1376-01-127-9541		PROPELLANT POWDER,SPDF F/5 IN 54
1376-01-127-9542		PROPELLANT POWDER,SPDF F/6 IN 47
1376-01-129-4679		PROPELLANT POWDER,M6,SPDN F/3IN 50
1376-01-129-4680		PROPELLANT POWDER,M6,SPD F/ 5 IN 38
1376-01-129-4681		PROPELLANT POWDER,M6,SPDN F/16 IN 47 CAL
1376-01-129-4682		PROPELLANT POWDER,M1, SPDN F/20MM
1376-01-129-4683		PROPELLANT POWDER,M1, SPDN F/40MM
1376-01-129-8053		PROPELLANT POWDER,SPD,PYROCELLULOSE F/4 IN 50
1376-01-129-8055		PROPELLANT POWDER,SPD,PYROCELLULOSE F/8 IN 55
1376-01-129-8056		PROPELLANT POWDER,SPDB F/6 IN 47
1376-01-129-8057		PROPELLANT POWDER,SPDW F/8 IN 55
1376-01-129-8058		PROPELLANT POWDER,SPDW F16 IN 45
1376-01-129-8059		PROPELLANT POWDER F/ 5 INCH 38
1376-01-130-1974		PROPELLANT POWDER,M6 PROP SPDN F/8IN 55
1376-01-130-1975		PROPELLANT POWDER,SPDF F/8 IN 00
1376-01-132-1692		PROPELLANT POWDER,WC814, F/5.56MM BLANK M200
1376-01-132-1710		PROPELLANT POWDER,SPDW F/5 IN 38
1376-01-132-1710		PROPELLANT POWDER,SPDF F/3 IN 50
1376-01-132-7304		PROPELLANT POWDER,SPDW F/5 IN 54
1376-01-132-9160		PROPELLANT POWDER,BS-NACO F/5 IN 54
1376-01-133-7463		PROPELLANT POWDER,M10 FLAKE F/60MM INCR M204
1376-01-141-1060		PROPELLANT POWDER,M10,MP F/75MM, M309A1
1376-01-141-1230		PROPELLANT POWDER,M30,MP F/105MM M774
1376-01-141-1230		PROPELLANT POWDER,BS-NACO F/PROP CHG F/CANNON
1376-01-149-1702		PROPELLANT POWDER,M30,MP F/105MM APFSDS-T M833
1376-01-152-3078		PROPELLANT,SOLVENTLESS F/155MM RA M549A1 1CLASS
1376-01-152-3079		PROPELLANT,SOLVENTLESS F/155MM RA M549A1 2 CLASS
1376-01-164-3489		PROPELLANT, SHEET STOCK
1376-01-176-8765		PROPELLANT POWDER,M6+2 F/5 IN 54
1376-01-177-5974		SPT FORM 120MM M830/M831
1376-01-177-9229		PROPELLANT POWDER,JA-2, 15 IN STICK F/120MM XM 827
1376-01-177-9230		PROPELLANT POWDER,JA-2 F/120MM M829
1376-01-177-9231		PROP POWDER,DIGL-RP,14 IN STICK F/120MM XM 830/831
1376-01-177-9232		PROP POWDER,DIGL-RP,FORM B,4 IN STICK F/120MM
1376-01-177-9233		PROP POWDER,DIGL-RP,FORM C,F/120MM XM830/831
1376-01-177-9234		PROPELLANT POWDER,LKL F/120MM CTG XM865
1376-01-179-5974		PROP POWDER,DIGL-RP FORM D F/120MMXM830/831
1376-01-179-5974		PROPELLANT POWDER,DIGL-RP F/120MM CTG XM830/831
1376-01-180-3513		PROPELLANT POWDER,WC844 F/5.56MM TR M856
1376-01-180-3514		PROPELLANT POWDER,WC844T F/5.56MM BALL M855
1376-01-184-1696		PROPELLANT POWDER,IMR 4895 F/CTG 7.62MM M852
1376-01-187-7650		PROPELLANT POWDER,M14 F/105MM M490A1
1376-01-190-1114		PROPELLANT POWDER
1376-01-190-1115		PROPELLANT POWDER F/40MM SGT YORK SYSTEM

NSN	DODIC	NOMENCLATURE
1376-01-192-4164		PROPELLANT P OWDER,WC844 F/5.56MM BALL M855
1376-01-195-9610		PROPELLANT,DOUBLE BASE, SPHERIODAL F/5.56MM CTG
1376-01-203-7484		PROPELLANT POWDER SINGLE BASE F/CAL 45 BALL
1376-01-203-7489		PROPELLANT DOUBLE BASE WC844 F/5.56MM M855
1376-01-204-9784	MM07	PROPELLANT POWDER F/CAD/PAD
1376-01-204-9785	MM08	PROPELLANT POWDER F/CAD/PAD
1376-01-210-4040		PROPELLANT,DOUBLE BASE WC858 F/20MM M54A1
1376-01-213-5669		PROP POWDER,M31A1,SP 29 IN SLOTTED STICK F/155MM
1376-01-218-9319		PROPELLANT POWDER,M6 F/105MM CTG M327
1376-01-221-5664		PROPELLANT GRAIN F/CADS
1376-01-221-5665		PROPELLANT GRAIN F/CADS
1376-01-221-5666		PROPELLANT GRAIN F/IMPULSE CTG CCU-52A
1376-01-221-5667		PROPELLANT GRAIN F/IMPULSE CTG CCU-52A
1376-01-221-5745		PROPELLANT POWDER
1376-01-223-0934		PROPELLANT GRAIN F/CTG. ACT. INIT. M53/91/99
1376-01-223-0935		PROPELLANT GRAIN F/CADS
1376-01-223-0936		PROPELLANT GRAIN F/CADS
1376-01-223-0937		PROPELLANT GRAIN F/CADS
1376-01-223-0938		PROPELLANT GRAIN F/IMPULSE CTG M119
1376-01-223-0939		PROPELLANT GRAIN F/IMPULSE CTG CCU-56A
1376-01-224-0356		PROPELLANT GRAIN,M2 PROP F/IMP CTG MK 40 MOD 0
1376-01-227-9360		PROPELLANT GRAIN,M2 PROP F/CTG M31A2
1376-01-247-7208		PROPELLANT POWDER,M6 MIXTURE FORM C TYPE1..
1376-01-255-6279		PROPELLANT POWDER,M38 SPHERIODAL F/81MM PROP CHG
1376-01-262-5398		PROPELLANT POWDER,M8 PROP
1376-01-274-0751		PROPELLANT POWDER F/CAL 38 BALL/IMPULSE CTG M796
1376-01-279-1324		PROPELLANT GRAIN F/INITIATOR JAU-22B
1376-01-279-1325		PROPELLANT GRAIN F/CADS
1376-01-279-2452		PROPELLANT GRAIN F/INITIATOR JAU-22B
1376-01-279-2453		PROPELLANT GRAIN F/CADS
1376-01-281-1665		PROPELLANT GRAIN F/ROCKET MOTORS & FUZES
1376-01-283-0197		PROPELLANT POWDER F/ACRFT CANOPY REMOVER M151
1376-01-285-3107		PROPELLANT POWDER F/CTG IMPULSE 150
1376-01-291-7040		PROPELLANT POWDER WC859 F/20MM
1376-01-299-8859		PROPELLANT POWDER,BENITE STRANDS 30.2 IN LENGTH
1376-01-300-9526		PROPELLANT POWDER,WC440S F/CAL .50 BLANK
1376-01-306-1237		PROPELLANT GRAIN F/CADS MK 47
1376-01-306-1238		PROPELLANT GRAIN F/CADS
1376-01-315-9742		PROPELLANT POWDER,M43 F/105MM CTG M900 SERIES
1376-01-318-6315		PROPELLANT POWDER,BENITE STRANDS 8.25 IN LENGTH
1376-01-325-3586		PROPELLANT GRAIN,HPC-3N
1376-01-325-3587		PROPELLANT GRAIN,HPC-23N
1376-01-325-3588		PROPELLANT GRAIN,HPC-1N
1376-01-325-5071		PROPELLANT GRAIN F/IMPULSE CTG CCU-56A

NSN	DODIC	NOMENCLATURE
1376-01-325-5072		PROPELLANT GRAIN F/IMPULSE CTGS CCU-1B,11B
1376-01-325-5073		PROPELLANT GRAIN,M2 PROPELLANT
1376-01-325-5075		PROPELLANT POWDER,HPC-60 F/IMPULSE CTG CCU-106A
1376-01-325-5113		PROPELLANT GRAIN F/IMPULSE CTGS M141/146
1376-01-325-5114		PROPELLANT GRAIN F/IMPULSE CTG M37
1376-01-325-5115		PROPELLANT GRAIN,M8 PROP F/IMPULSE CTGS M43/44A
1376-01-325-5116		PROPELLANT GRAIN,M6 PROP F/IMPULSE CTG MK 18
1376-01-325-5117		PROPELLANT GRAIN F/DELAY CTG CCU-73A
1376-01-325-5118		PROPELLANT GRAIN F/IMPULSE CTG CCU-44A1
1376-01-335-5054		PROPELLANT POWDER,WC867 F/20MM CTG
1376-01-342-3843		PROPELLANT POWDER,M10 F/IMPULSE CTG M42A1
1376-01-342-3844		PROPELLANT POWDER,IMR 5010
1376-01-362-6503		PROPELLANT POWDER,PROP WC 750
1376-01-368-7116		PROPELLANT POWDER,PROP WC 845 F/5.56MM TR&BALL
1376-01-370-6678		PROPELLANT POWDER,WCR845 F/TR M856
1376-01-373-5883		PROPELLANT GRAIN F/120MM M865
1376-01-396-0257		PROPELLANT GRAIN F/120MM M831A1
1376-01-426-1542		PROPELLANT POWDER,M1 PROP F/CTG M865E2

APPENDIX D

COMMON PROPELLANT COMPOSITIONS

PROPELLANT COMPOSITIONS

(THE NUMBERS IN THESE CHARTS ARE APPROXIMATE PERCENTAGES BY WEIGHT [1])

COMPONENT / PROPELLANT MODEL NUMBER	M1	M2	M5	M6	M7	M8	M9	M10	M12	M13	M14
Nitrocellulose	85.00	77.45	81.95	87.00	54.60	52.15	57.75	98.00	97.70	57.30	90.00
Nitroglycerin		19.50	15.00		35.50	43.00	40.00			40.00	
Nitroguanidine											
Dinitrotoluene	10.00			10.00							8.00
Dibutylphthalate	5.00			3.00							2.00
Diethylphthalate						3.00					
Diphenylamine	1.00			1.00				1.00	0.80	0.20	1.00
Ethyl Centralite		0.60	0.60		0.90	0.60	0.75			1.00	
Barium Nitrate		1.40	1.40								
Potassium Nitrate		0.75	0.75			1.25	1.50				
Potassium Perchlorate					7.80						
Lead Carbonate	1.00										
Potassium Sulfate	1.00			1.00				1.00	0.75	1.50	
Tin									0.75		
Carbon Black					1.20					0.05	
Graphite		0.30	0.30					0.10			
Cryolite											

THE INFORMATION IN THIS CHART IS CONTINUED ON THE NEXT PAGE

[1] The information contained in this chart is an approximation only. Specific information regarding percentages and tolerances of components should be obtained from the appropriate specifications and standards. This listing is not intended to be a collection of all propellant compositions used by the military, but rather only examples of some typical compositions.

PROPELLANT COMPOSITIONS

(THE NUMBERS IN THESE CHARTS ARE APPROXIMATE PERCENTAGES BY WEIGHT)

COMPONENT / PROPELLANT MODEL NUMBER	M15	M17	M18	M26	M26E1	M30	M30A1	M30A2	M31	M31A1	IMR
Nitrocellulose	20.00	22.00	80.00	67.25	68.70	28.00	28.00	27.00	20.00	20.00	100.0
Nitroglycerin	19.00	21.50	10.00	25.00	25.00	22.50	22.50	22.50	19.00	19.00	
Nitroguanidine	54.70	54.70				47.70	47.00	46.25	54.70	54.00	
Dinitrotoluene											8.00
Dibutylphthalate			9.00						4.50	4.50	
Diethylphthalate											
Diphenylamine			1.00							1.00	0.70
Ethyl Centralite	6.00	1.50		6.00	6.00	1.50	1.50	1.50			
Barium Nitrate				0.75							
Potassium Nitrate				0.70				2.75			
Potassium Perchlorate											
Lead Carbonate											
Potassium Sulfate							1.00		1.50	1.50	1.00
Tin											
Carbon Black											
Graphite		0.10		0.30	0.30	0.10					
Cryolite	0.30	0.30				0.30			0.30		
2-Dinitrophenyldiamine									1.50		

THE INFORMATION IN THIS CHART IS CONTINUED FROM THE PREVIOUS PAGE

SUBSTITUTES AND ADDITIVES USED IN PROPELLANT COMPOSITION

PURPOSE / MATERIAL	Reduce Hygroscopicity	Stabilizer	Plasticizer	Deterrent	Reduce Flame Temperature	Reduce Flash	Reduce Bore Erosion	Increase Electrical Conductivity	Control Burning Rate	Source of Oxygen	Retards Ignition	Increases Ignitability	Moisture Proof Coating
Nitroglycerin	X		X							X		X	
Nitroguanidine					X	X	X						
Dinitrotoluene	X		X	X			X		X				X
Dibutylphthalate	X		X	X	X	X	X		X				
Diethylphthalate						X	X		X				
Diphenylamine**		X											
Ethyl Centralite*	X	X	X	X	X	X	X		X				X
Barium Nitrate						X							
Potassium Nitrate						X							
Potassium Perchlorate						X			X	X			
Potassium Sulfate						X							
Tin (Lead)***													
Carbon Black												X	
Graphite								X			X		
Cryolite						X							
2-Dinitrophenyldiamine		X	X										
Methyl Centralite			X	X		X	X		X				
Triacetin			X			X							

* Stabilizer for double base propellant
** Stabilizer for single base propellant
*** Decoppering or weapon cleaning agent

Ethyl Cellulose and Cellulose Acetate are inhibiters. They retard or slow down the burning rate.

APPENDIX E

POINTS OF CONTACT

NOTE: Suggestions to expand POC list are welcomed. Installation level points of contact might prove useful in future editions.

1. IOC: Ammunition Surveillance Division

    Mail Address: Commander
    HQ, IOC
    ATTN: AMSIO-QAS
    Rock Island, IL 61299-6000

    Individual Contact: **Robert Lorenz**
    Telephone: DSN 793-7572/7587, Commercial (309) 782-7572
    E-mail: rlorenz@ria-emh2.army.mil

2. USADAC: Logistics Review and Technical Assistance Office

    Mail Address: Director
    USADAC
    ATTN: SIOAC-AV
    Savanna, IL 61074-9639

    Individual Contact: **Elena Graves**
    Telephone: DSN 585-8052, Commercial (815) 273-8052
    E-mail: gravese@dac-emh1.army.mil

3. ARDEC (Picatinny): Army Propellant Surveillance Laboratory

    Mail Address: Commander
    ARDEC
    ATTN: AMSTA-AR-AEE-WEE
    Picatinny Arsenal, NJ 07806-5000

    Individual Contact: **Diana-Lynn Herbst**
    Telephone: DSN 880-2560/4914, Comm (201) 724-2560/4914
    E-mail: dlarweth@pica.army.mil

4. NSWC Indian Head: NAVSEA Gun Propellants:

Mail Address: Commander
Indian Head Division
Naval Surface Warfare Center
ATTN: Code 6210F (David Lee)
101 Strauss Ave.
Indian Head, MD 20640-5035

Individual Contact: **David Lee**
Telephone: DSN 354-4521, Commerical (301) 743-4521
E-mail: 6210f@mail.ih.navy.mil

5. United States Marine Corps Gun Propellants

Mail Address: Commander
Naval Ordnance Center/Pacific Division
Fallbrook Detatchment
ATTN: Code 5123 (Mr. Wissa)
700 Ammunition Road
Fallbrook, CA 92028-3187

Individual Contact: **Rami Wissa**
Telephone: DSN 873-3738, Commercial (619) 731-3738
E-mail: wissar@fb.sbeach.navy.mil

6. Naval Air at China Lake

Mail Address: Commander
Naval Air Warfare Center, Weapons Division
ATTN: Code 473P50D (Dr. Pakulak)
1 Administration Circle
China Lake, CA 93555-6100

Individual Contact: **Mary Pakulak**
Telephone: DSN 437-7592, Commercial (760) 939-7592
E-mail: mary_pakulak@clplgw.chinalake.navy.mil

State of Louisiana

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GOVERNOR

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MAJOR GENERAL
THE ADJUTANT GENERAL
(504) 278-8357
FAX (504) 278-8210

February 5, 2013

The Honorable Leon E. Panetta
Secretary of Defense
1400 Defense Pentagon
Washington, DC 20301-1400

RE: Request for Transportation and Storage of M6 Propellant Pursuant to 10 U.S.C. 2692

Dear Secretary Panetta:

The State of Louisiana, through the Military Department ("LMD"), hereby requests assistance from the Department of Defense for the transportation and storage of excess M6 propellant currently located at Camp Minden, Louisiana. The M6 propellant is a hazardous material derived from the demilitarization of the M119A2 Propelling Charge by Explo Systems, Inc. ("Explo"), a tenant of LMD located at Camp Minden. The propellant was used in connection with an activity of the DoD as provided in 10 U.S.C. 2692 (b)(1). The excess propellant was produced by Explo under the terms and conditions of its contract with DoD (contract no. W52P1J-10-C-0025).

While performing work for the DoD under its contract, Explo illegally and improperly stored large amounts of M6 propellant on the premises of Camp Minden without the knowledge or consent of the State of Louisiana. Explo's actions in this regard violate state and federal law. Explo's illegal activities were discovered by the Louisiana State Police during a routine inspection of their operations. Explo is cooperating with law enforcement officials and has agreed to voluntarily remove the improperly stored propellant.

On January 23, 2013, Explo requested assistance from DoD for storage of the excess propellant generated under the DoD contract. This request was made because the amount of propellant far exceeds the storage capacity of Camp Minden. Explo's request was denied by the DoD. The State of Louisiana makes this request of DoD solely because the existence of the improperly stored propellant is a safety risk to Camp Minden and to the neighboring town of Doyline, LA. This request in no way implies that the State of Louisiana intends to take possession of or responsibility for the propellant, which is solely the property of Explo. We intend to hold Explo or its successor responsible and accountable for creating this extremely hazardous situation, including the cost of disposal of the propellant.

Under referenced Subsection (b)(3) of the statute, the Secretary of Defense is authorized to assist agencies responsible for State law enforcement in storing or disposing of explosives when no alternative solution is available. Our tenant, Explo Systems, Inc. has exhausted all available on site storage located at Camp Minden, and has been unable to acquire suitable storage after multiple attempts at multiple locations. The State of Louisiana has exhausted its storage capacity and has no available resources to properly store the excess propellant.

Additionally, the Secretary has the authority, under Subsection (c) of the statute to grant exceptions when essential to protect the health and safety of the public from imminent danger. LMD specifically requests that DoD transportation assets and storage magazines be provided to transport and store the excess propellant currently under the custody of Explo. In order to accomplish this, LMD requests that you grant an exception to Subsection (a) of 10 U.S.C. 2692 to allow storage of the excess M6 propellant on DoD installations. Granting of this exception is essential to protect the health and safety of the public inside and around Camp Minden, including the town of Doyline, LA, which is directly adjacent to the installation.

Thank you in advance for your cooperation and assistance.

Sincerely,

Glenn H. Curtis
Major General, Louisiana National Guard
The Adjutant General

Copy Furnished:
Mr. Paul W. Rainwater, Chief of Staff, Office of the Governor
Colonel Michael D. Edmonson, Superintendent, Louisiana State Police
Brigadier General John McGuiness, Commander, Picatinny Arsenal

SECRETARY OF THE ARMY
WASHINGTON

MAR 1 2 2013

Major General Glenn H. Curtis
The Adjutant General
Louisiana National Guard
6400 St. Claude Avenue
Jackson Barracks
New Orleans, LA 70117

Dear General Curtis:

The Secretary of Defense asked me to respond on his behalf to your February 5, 2013 letter concerning the possible transport and storage of propellant known as "M-6," which is currently located at Camp Minden, Louisiana. Your letter states this propellant is the property of a company known as Explo Systems, Inc. (Explo), which has a lease with the Louisiana National Guard to use certain portions of Camp Minden for its operations.

Regrettably, the Department of Defense (DoD) has neither the authority nor funds available to seize Explo's private property (i.e., the propellant located at Camp Minden) and assume responsibility for its transportation elsewhere for storage, treatment or disposal. 10 USC § 2692 generally prohibits DoD from allowing the storage, treatment or disposal of any hazardous materials not owned by DoD on any military installation, except under limited exceptions established in that statute. I have been authorized to inform you that the information in your letter and otherwise available to DoD indicates that storage, treatment or disposal of Explo's materials on a DoD installation would not meet the criteria for any of the statutory exceptions to the Section 2692 prohibition. Additionally, DoD does not have an installation with the environmental operating permits that would be required to allow for the receipt and treatment of privately owned hazardous waste transported from another location.

Should you believe it beneficial, DoD will arrange for a team of technical experts from the DoD Explosives Safety Board (DDESB) and the U.S. Army Technical Center for Explosives Safety to visit Camp Minden to assist in evaluating the amount of propellant Explo has in storage and its condition. These technical experts would be able to offer advice on potential explosive safety hazards associated with the materials and actions that might be taken to mitigate safety hazards that are identified. This team would not have authority to direct Explo or any other party to take or refrain from taking action with regard to Explo's propellant or operations, or to assume responsibility on behalf of DoD for this propellant. The team's technical expertise may be helpful to you and other State officials, or Explo, in deciding how to proceed. The point of contact for this team is Colonel Leo Bradley, Army Military Representative, DDESB, phone number

571-372-6765 or email leo.e.bradley.mil@mail.mil. For additional information regarding this action please contact Mr. JC King, Army DDESB Voting Member, phone number (703) 697-5564, email jc.king@us.army.mil.

I regret that we cannot be of more assistance in this matter. Thank you for all you do for our National Guard Soldiers and Families in Louisiana and for your dedicated service to our Nation.

Sincerely,

John M. McHugh

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
INSTALLATIONS, ENERGY AND ENVIRONMENT
110 ARMY PENTAGON
WASHINGTON DC 20310-0110

18 April 2013

MG Glenn H. Curtis
The Adjutant General
Louisiana National Guard
6400 St. Claude Avenue
Jackson Barracks
New Orleans, LA 70117

Dear General Curtis:

Enclosed is the report from the technical assistance visit you requested in your letter of March12, 2013 regarding the potential short- and long-term hazards associated with the M6 propellant that Explo Systems, Inc. (Explo) stores and processes for recycling and commercial sale at the Louisiana National Guard's (LANG) Camp Minden. The attached report provides recommendations LANG and the Louisiana State Police (LASP) may consider to improve the explosives safety posture at Camp Minden.

The Army's technical assistance team, which conducted its review on 2 and 3 April 2012, focused on Explo's storage and processing of M6 propellant The team did not review Explo's personnel qualifications, operating procedures, and/or its procedures for security or accountability of explosives. LANG may want to consider evaluating these matters.

The team was informed there may be other commercial entities performing operations involving explosives at Camp Minden, and that LANG may also be leasing facilities to other commercial entities for non-munitions-related work. LANG did not request the team evaluate these areas or operations, nor did it make them available for the team's evaluation. Because operations of this nature may be cause for concern, LANG is encouraged to evaluate all operations at Camp Minden to help ensure the safety of personnel working on Camp Minden, the security of LANG's operations, and the safety of the public. I recommend LANG contact the National Guard Bureau's Quality Assurance Specialist (Ammunition Surveillance), Mr. Clark Holmes, to request any assistance it may need to address these and other explosives safety-related matters.

The team that visited Camp Minden remains available to LANG to provide further advice on the Explo materials at Camp Minden. Additionally, the US Army Technical Center for Explosives Safety is a valuable resource for all Army and National Guard activities.

I understand Explo continues to reduce the quantity of propellant it stores at Camp Minden and is moving remaining propellant into storage. As such, the explosive hazards posed on Camp Minden and to nearby communities are substantially reduced. This is good news for Camp Minden's neighboring communities and for state officials who are providing oversight of the situation. My point of contact for this matter is Mr. J. C. King, Director for Munitions and Chemical Matters, and the Army's Department of Defense Explosives Safety Board Voting Member, at (703) 697-5564; james.c.king4.civ@mail.mil.

Sincerely,

Hershell E. Wolfe
Acting Deputy Assistant Secretary of the Army
(Environment, Safety and Occupational Health)

Enclosure

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Department of Army

Report
of
Explosives Safety Assistance Visit
to
Louisiana Army National Guard's
Camp Minden

April 18, 2013

Final Report of Explosives Safety Assistance Visit to Camp Minden

1. Background.

a. On 12 March 2013, The Adjutant General (TAG), Louisiana National Guard (LANG) requested (Enclosure) the Army provide a technical assistance team to assess stored propellant at the State-owned Camp Minden, Louisiana (LA), and make recommendations for potential mitigation measures. TAG specifically, requested the team conduct an assessment of the potential short- and long-term hazards associated with M6 propellant being processed and stored on Camp Minden by Explo Systems, Inc. (Explo), a commercial firm. Explo has a lease from the State for certain property on Camp Minden, which it uses for the purpose of conducting demilitarization operations under Contract W52P1J-10-C-0025 for the demilitarization of D533 Charges, Propellant, 155mm, M119A2, and Explo's subsequent commercial recycling operations of the demilitarized propellant.

b. On 2 and 3 April, a team, under the leadership of COL Leo Bradley, Army Military Representative to the Department of Defense Explosives Safety Board (DDESB), conducted the requested technical assistance visit (TAV). The team consisted of:

- COL Leo Bradley, DDESB
- Mr. James Young, Quality Assurance Specialist (Ammunition Surveillance), Department of the Army, G4
- Mr. Paul Cummins, Mr. Greg Heles, and Ms. Libzent Odom, US Army Technical Center for Explosives Safety (USATCES)
- Mr. James Lane, Defense Ammunition Center.

c. COL Bradley provided COL Ronnie D. Stuckey, Commander, Camp Minden, an initial report of the team's assessment. This is the final report of that visit.

2. Executive Summary. COL Stuckey, and Officer John Porter, Deputy Command Technician, and Shelly Hopkins, Criminal Investigator, LA State Police's (LASP) Hazardous Material and Explosives Control Unit, provided the team a thorough in-briefing. After touring the portion of the facility leased and used by Explo and gaining access to installation facility maps, the team conducted an explosives safety quantity distance (ESQD) analysis. This analysis detailed the original situation in Explo's area of operations (Figure 1) in November 2012, as the LASP described; the situation on 2 and 3 April (the current situation) (Figure 2); and a proposed solution (Figure 3) that would provide improved public safety by making changes to Explo's explosives-related operations and propellant storage locations. During the TAV, the team observed several deviations from standard Department of Defense (DoD) explosives safety practices as identified in DoD 6055.09-M (Volumes 1 to 8), DoD Ammunition and Explosives Safety Standards. Based on its assessment, the team recommends LANG initiate the following actions as quickly as possible:

- Consider all areas within the S-Line (an Explo facility) as an explosives storage site, and prohibit explosives operations within the area, including Explo's current repacking operation and its proposed aluminum reclamation operation.

- Reduce the quantity of propellant in building 1607 to 591,805 lbs of M6 propellant. Reduce the amount of M6 propellant in other buildings to the quantities provided in Figure 3.
- Identify the location of all M6 propellant from Lot IND82E-070170, segregate, and dispose of it as soon as possible. The team's review of the DoD lot numbers shipped to Camp Minden revealed that this Lot has been classified with stability category "C."
- Move the LASP's administrative offices outside of the "marginal" arc of Figure 3.

3. Way Ahead. Since November 2012, when LASP discovered the potential explosive hazards posed by M6 propellant at Camp Minden, LANG and LASP have taken effective action to protect the public. Implementation of the above recommendations will further increase public safety; however, their implementation will not bring the S-Line into conformity with DoD 6055.09-M. The team strongly recommends LANG and the Commander, Camp Minden, consult with explosives safety experts at the National Guard Bureau and, if required, seek further advice from the technical assistance team as the situation at the Explo's area of operations at Camp Minden improves.

Explosives Safety Quantity Distance (ESQD) Analysis

In its ESQD analysis, the team applied the below universal assumptions:

- The TNT equivalency of M6 propellant is 0.65 (65 percent (%)).
- The responsible authority accepts the hazards and risks to the rail yard, rail cars, and any other facilities within ESQD arcs.
- The explosives limits shown on the drawing are not exceeded.

<u>S-Line ESQD Analysis</u>:

Original Situation November 2012 (Figure 1)

Figure 1 shows the situation on the S-Line in November 2012. The ESQD situation depicted is for 6.5M lbs of TNT, which is the TNT equivalency of 10M lbs of M6 propellant. The team calculated the TNT equivalency by simply adding all the explosives material present on the S-Line at that time.

In its ESQD analysis of the S-Line's original situation, the team assumed that all 10M lbs of M6 propellant on the line in November 2012 would react with a prompt propagation as a Hazard Division (HD) 1.1 – a reaction of 6.5M lbs net explosives weight (NEW).

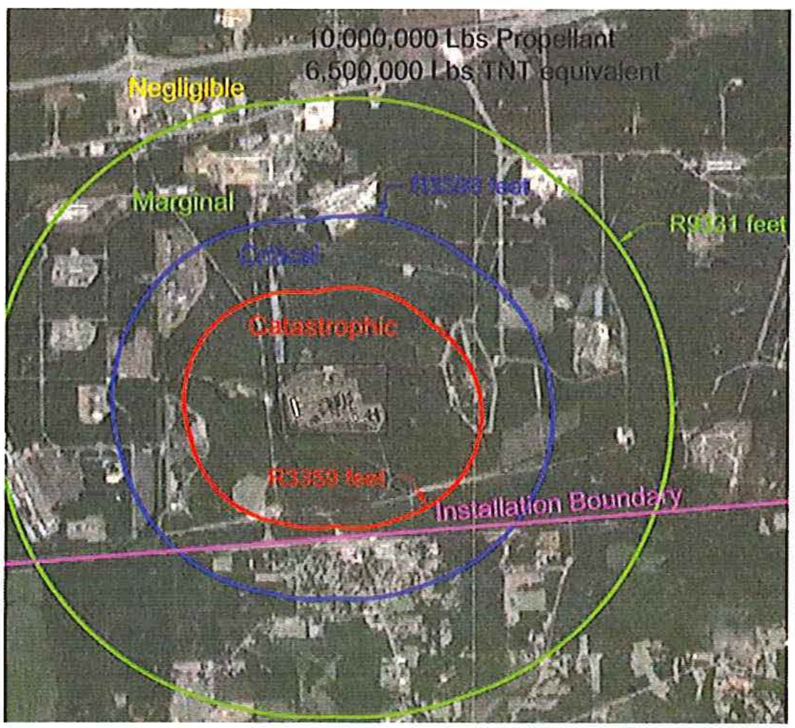


Figure 1 – Original Situation (November 2012)

Current Situation April 2013 (Figure 2)

Figure 2 shows the current situation. The ESQD situation depicts the team's "best estimate" of the NEW of M6 propellant on the S-Line as of April 2013.

In its ESQD analysis of the current situation, the team assumed:

- The S-Line is only an explosives storage site. Only operations directly related to the storage of explosives would be allowed to be performed within the S-Line. Therefore, the repackaging operations currently performed at the S-Line would be discontinued. Additionally, among other non-storage related activities, the shipping and receiving office would be moved, and aluminum recovery operations as well as demilitarization-related operations would not be allowed to be preformed within the S-Line.
- There are three inter-magazine distance (IMD) violations on S-line.
  - The first is from building 1607 to building 1645. Considering both buildings only contain M6 propellant, it is not anticipated that propagation will occur between these buildings. Therefore, the IMD violation will be discounted.
  - The second is from building 1607 to building 1610. Considering both buildings only contain M6 propellant, it is not anticipated that propagation will occur between these buildings. Therefore, the IMD violation will be discounted.
  - The third is between buildings 1610 and 1650. Therefore, for the "Current Situation" analysis, buildings 1610 and 1650 will be referred to as the "group of 2," with the explosives totaled and treated as one explosives storage location. IMD is maintained between the "group of 2" and all other explosives storage buildings.
- The small wing on building 1607 that extends east towards building 1610 does not contain any explosives materials. Non-explosives materials are allowed.

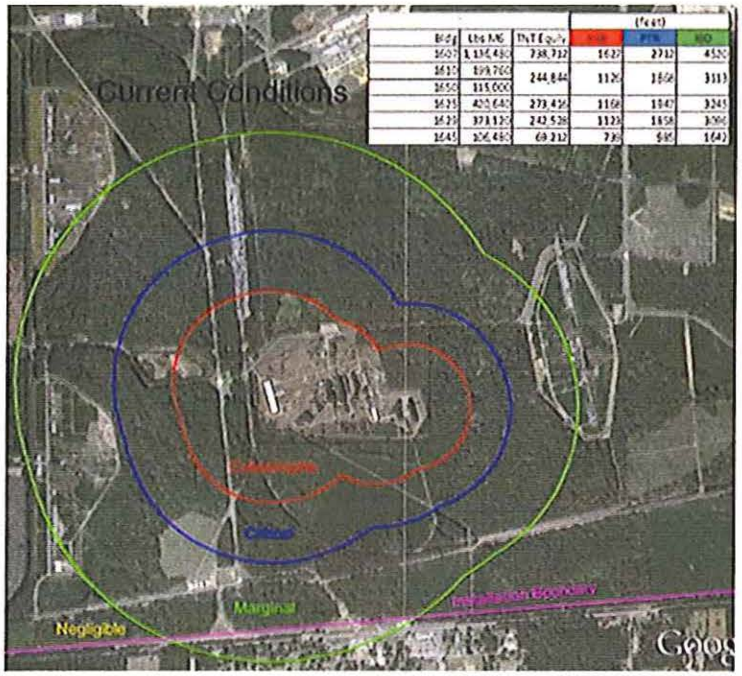


Figure 2 – Current Situation (Apr 13)

Proposed Solution (Figure 3)

Figure 3 shows the proposed solution. The proposed solution is a "future state" that will meet DoD 6055.09-M's criteria and reduce the threat to the public to a "negligible" level.

In its ESQD analysis for the proposed solution, the team assumed:

- S-Line is only an explosives storage site. Only operations directly related to the storage of explosives should be allowed to be performed within the S-Line. Therefore, the repackaging operations currently performed at the S-Line would be discontinued. Additionally, among other non-storage related activities, the shipping and receiving office would be moved, and aluminum recovery operations as well as demilitarization-related operation would not be allowed to be preformed within the S-Line.

- For the proposed solution, buildings 1610, 1617, 1619, and 1650 will be referred to as the "group of 4," with the explosives totaled and treated as one explosives storage location. IMD is maintained between the "group of 4" and all other explosives storage facilities. Grouping these four buildings as one explosives location maximizes the allowable explosives storage within S-line.

- The proposed solution meets DoD 6055.09-M's criteria, with respect to IMD, and provides an acceptable level of protection for the public.

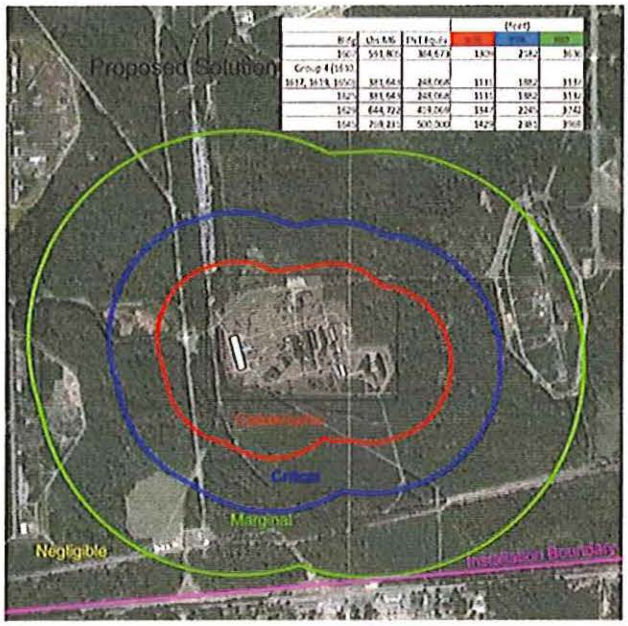


Figure 3 – Proposed Solution

Hazard Zone Definitions

The below provide a broad definition of the different types of consequences expected within the ESQD hazard zones depicted in Figures 1 through 3.

- Catastrophic: Delayed propagation of an explosion may occur from fire brands or equipment failure at the exposed sites. Personnel in the open will likely be killed by direct action of blast, by being struck by fragments and building debris, or by physically being thrown against a hard surface. Personnel in buildings may be injured or killed by destruction/collapse of the building. Damage to un-strengthened buildings will be serious and approximate 50 percent or more of the total replacement cost (minimum). Transport vehicles will incur extensive, but not severe, body and glass damage consisting mainly of dishing of body panels and cracks in shatter-resistant window glass.

- Critical: Personnel in the open are likely to be injured or killed by fragments and debris, depending largely upon the structure housing the explosives, the amount of explosives, and its fragmentation characteristics. Injuries are principally caused by broken glass and internal building debris. Un-strengthened buildings are likely to sustain damage approximating 20 to 50 percent of the replacement cost depending on building type and distance. Vehicles on the road should suffer little damage unless hit by a fragment or unless the blast wave causes momentary loss of control.

- Marginal: Personnel in structures are provided a high degree of protection from death or serious injury, with likely injuries principally being caused by broken glass and building debris. Personnel in the open are not expected to be injured seriously directly by the blast but these personnel may receive injuries and possible death from fragments and debris, depending largely upon the structure and the amount of explosives and its fragmentation characteristics. Facility structure and fragmentation characteristics will determine the probability of marginal .vs. negligible consequences. Un-strengthened buildings are likely to sustain damage from 5 to 20 percent of the replacement cost depending on distance. Exposed equipment and material may be damaged by fragments and become unusable.

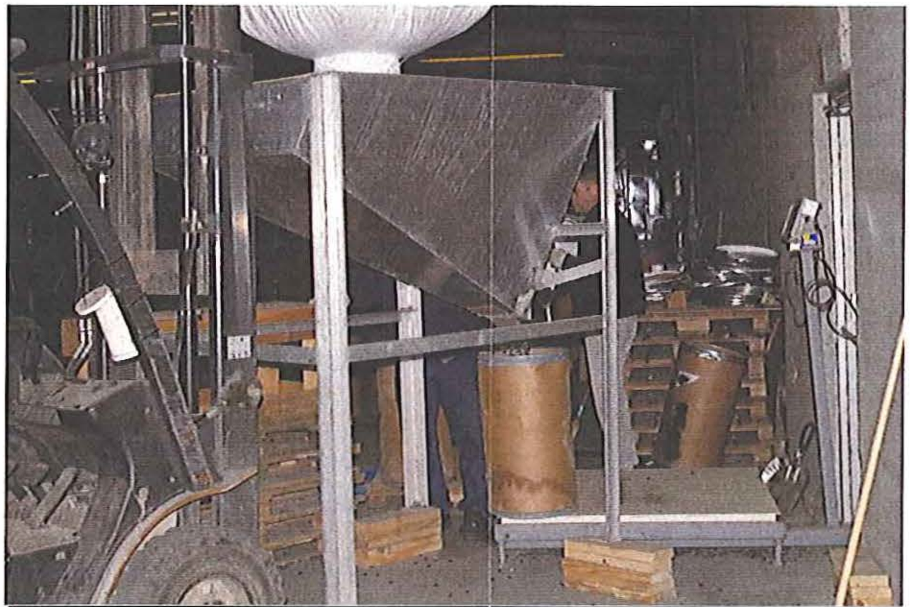
- Negligible: Personnel beyond the green arc are not likely to be injured or killed by fragments. Fragments can occur at these distances, but the probability of hitting a person is unlikely. On DoD installations, DoD accepts this level of risk through policy and regulation. Un-strengthened buildings are likely to sustain only minor damage, 5 percent maximum, primarily from fragments and glass breakage.

Additional Observations and Recommendations

- **Observation**: Building 1607 is used as a storage location for approximately 1M lbs of M6 propellant. In addition, Explo conducts operations involving the receipt, repackaging, and shipment of M6 propellant this site.

  Recommendation: Prohibit Explo from repackaging propellant in building 1607 and move the repackaging operation to another location that complies with DoD 6055.09-M. Limit building 1607's use to storage of M6 propellant.

  Reference: DA Pam 385-64, Ammunition and Explosives Safety Standards, paragraph 2-5, Personnel and Explosives Limits.

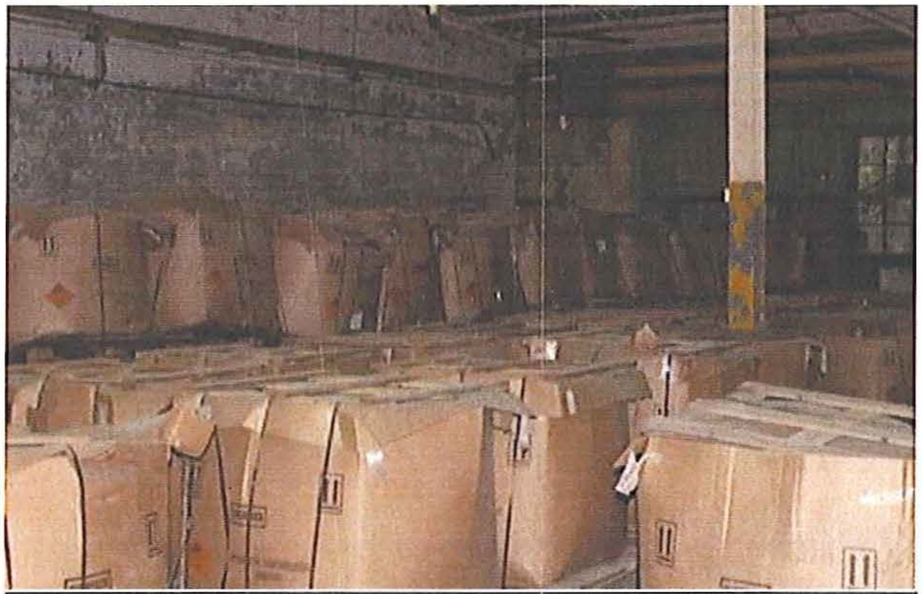


Propellant repackaging operations in building 1607

- **Observation**: The amount of propellant in storage in building 1607 creates ESQD violations.

  Recommendation: Reduce the propellant in storage in building 1607 to no more than 591K lbs. Limit building 1607's use to storage of M6 propellant. Prohibit the storage of hazardous materials, other than M6 propellant.

  Reference: DA Pam 385-64, Chapter 8, Explosives Safety Separation Distance (Quantity-Distance).



M6 Propellant in 880 lb bulk pack, Bldg 1610 (typical)

- **Observation**: The explosives in S-Line violate DoD 6055.09-M's explosives safety compatibility rules - if IMD is not met, all explosives must be treated as being at one location. M6 propellant, Tritonal, hazardous waste (pink water) and explosives residue (i.e., tar mixed with TNT) from a previous TNT/Tritonal melt-out operation, and Explosive D (ammonium picrate) are all stored within the S-Line (in buildings1619 and 1617).

  Recommendation: Remove, segregate and store explosives per DoD 6055.09-M's explosives safety compatibility and mixing rules. Comply with DoD 6055.09-M's criteria for storage of waste military munitions. Prohibit the storage of hazardous waste with explosives.

  References:

  - DoD 6055.09-M, V1, Table 7-2, Storage Compatibility Group (SCG) Mixing Chart for Storage.
  - DoD 6055.09-M, V7, Enclosure 5, Special Storage Procedures for Waste Military Munitions.

  DA Pam 385-64, paragraph 2-7.a.(4) – *At a minimum, hazardous waste material will be removed from AE and other operating facilities and taken to an approved disposal area or temporary collection point at the end of each shift. (b) Hazardous waste material should not be "stored" in the disposal area, but disposed of as soon as possible after arrival.*

Tritonal Flaking Belt – Building 1619

Tritonal scraps located in Building 1619 generated from Tritonal flaking operation

TNT Contaminated Water (red water/pink water)

- **Observation**: There was no static-electrical grounding or bonding on metal conveyers or hoppers (bonded and/or grounded conductive work surfaces). Personal protective equipment (PPE) (e.g., conductive shoes, wrist-stats, cotton garments) is not being used to prevent buildup of static electrical charges.

  Recommendation: Prohibit the use of this equipment until it is grounded and/or bonded per DA PAM 385-64. Provide operators appropriate PPE.

  References:

  - DA Pam 385-64, Section II, Static Electricity, paragraph 17-10. *General requirements – All machinery and equipment such as mixers for pyrotechnic, propellant, and explosive compositions, screening and sifting devices, assembly and disassembly machines, elevators, defusing machines, presses, hoppers, and all associated equipment involved in loading or processing explosives or explosives materials will be bonded to the earth electrode subsystem.*
  - DA Pam 385-64, Chapter 2, General Safety
  - 29 CFR 1910, Subpart 1 - personal protective equipment.

- **Observation**: The electric scale used to weigh propellant drums is connected to a standard 110 volt outlet (spark hazard). The outlet is located directly above open containers of bulk propellant. Several pallets of loaded drums are stored within 5 feet of the scale and download operation. Loose propellant observed wedged between the base of the scale and the platform.

Recommendation: Discontinue this operation until the above are addressed. Determine the requirement for explosion proof electrical connections and install where required. Perform a comprehensive cleanup of the area to remove lose and/or visible propellant and other explosive residues. Develop spill cleanup procedures and implement them.

Reference: DoD Manual 6055.09-M, V2, Enclosure 3, Electrical Standards; NFPA 70.

- **Observation**: Equipment used at propellant repack operations have electric motors, but explosive proof electrical outlets are not installed.

  Recommendation: Determine if this operation is a Class II hazardous location. Determine if the proper equipment and electrical connections are being used. If not, install and use.

  Reference: DA Pam 385-64, paragraph 17-6, Electrical Motors for Hazardous Locations: *Electrical motors should not be installed in a room or building which is a Class I or II hazardous location. They should have no connection to the building except through glands or apertures adequately sealed against entrance of hazardous materials either into the location or into the motor itself.*

- **Observation**: Deluge systems are not in place at the propellant download operation.

  Recommendation: Apply the "best practice" for operations involving exposed propellant by installing required deluge systems.

  References:

  - DoD Manual 6055.09-M, V, Enclosure 9, Personnel Protection, V1.E9.3.2.4. *Personnel protection may be achieved by: using fire detection and extinguishing systems (e.g., infrared actuated deluge system) in those areas where exposed, thermally energetic materials that have a high probability of ignition and a large thermal output are handled.*
  - DA Pam 385-64, paragraph 6-19, Deluge Systems for Explosives Operations.

- **Observation**: Exposed electrical wires and motors are on equipment used to crush metal containers.

  Recommendation: Discontinue use of this equipment until it meets electrical safety standards and is in proper working order.

  Reference: DA Pam 385-64, Chapter 17, Electrical Hazards and Protection.

- **Observation**: Tools used in the repack operations are not the non-sparking variety normally required for explosive operations.

  Recommendation: Ensure the proper hand tools be used for explosive operations.

  Reference: DA Pam 385-64, paragraph 2-6 h. – *Only authorized and properly maintained tools, including hand tools, that are approved for use in locations having hazardous concentrations of flammable dusts, gases, vapors, or exposed explosives will be used. Safety hand tools will be constructed of non-sparking and /or spark-resistant materials (wood, brass, titanium) that under normal conditions of use will not produce sparks.*

- **Observation**: Cleaning supplies and flammable chemicals (sweeping compound, cleaners, solvents, paints, anti freeze, hydraulic fluid, and acetone) are stored and scattered throughout the S-Line. A considerable amount of scrap wood, trash, and paper debris, litters the building as well.

  Recommendation: Remove cleaning supplies and/or flammable chemicals from the operations and storage areas of the S-Line. Store this type material in a secure location, separate from explosives storage or operating area. Perform general housekeeping by removing scrap wood, trash, and combustible packing materials.

  Reference: DA Pam 385-64, paragraph 2-7: *Ammunition AE storage, handling and operating facilities and area (AE facilities) will be maintained free of debris and rubbish, particularly the accumulation of oily rags or other material subject to spontaneous ignition. Paragraph 17-10 (3) (C) Solvents.*

- **Observation**: Diesel powered forklifts are being used in operational areas where M6 propellant is present. The team observed sparks emitting from an engine compartment of one forklift.

  Recommendation: Discontinue use of diesel forklifts in buildings and storage magazines containing explosives. Use electric forklifts and pallet jacks in operational areas.

  Reference: DA Pam 385-64, paragraph 2-17 (6) – *When necessary for efficient operation, battery-powered MHE is permitted to be used in buildings or magazines containing AE or other hazardous materials.*

- **Observation**: Lightning protection appeared to be deficient or in disrepair. Building 1607 had been an inert warehouse. As such, lightning protection for this building may have been omitted or designed to a lesser standard.

Recommendation: Implement procedures to warn of an approaching electrical storm, discontinue explosive operations, and leave the explosive area during such storms. Upgrade the lightning protection of all explosives storage locations to comply with NFPA 780, DOD 6055.09-M and DA Pam 385-64.

Reference: As stated.

- **Observation**: Inadequate grounds keeping at S-Line increases the likelihood of a fire reaching the stored explosives within the S-Line.

  Recommendation: Maintain a 50-foot fire break around the S-Line. Remove large accumulations of combustible materials (grasses, trees, pine needles, inert storage, etc.) within the S-Line.

  Reference: DA Pam 385-64, paragraph 6-8, Fire Prevention Requirements

- **Observation**: Explosive operators were wearing gloves, but no other PPE, such as coveralls and eye protection was observed.

  Recommendation: Ensure personnel wear the proper PPE.

  References:

  - DA Pam 385-64, Chapter 2, General Safety
  - 29 CFR 1910 subpart 1- personal protective equipment.

- **Observation**: Emergency destruction of 2.5M pounds of propellant may be required at some point.

  Recommendation: Ensure the proper equipment, facilities, explosive weights, and separation distances are used in burning of propellant.

  Reference: DoD 5055.09-M, V5, Enclosure 3, Areas Used for Intentional Burns and Detonations.

- **Observation**: M6 Propellant Lot IND82E-070170 is stability category "C," indicating it is approaching a potentially hazardous stability condition. (See the below explanation for the Stability Category Codes.)

  Recommendation: Any lot found with Lot Index Number 070170 should be segregated and disposed of as soon as possible per Army Notices of Ammunition Reclassifications (NAR) 11-0967.

  Reference: Propellant management Guide, December 2003 (see table below).

PROPELLANT MANAGEMENT GUIDE DECEMBER 2003

Table 2-1 Stability Category Codes

STABILITY CATEGORY	PERCENT EFFECTIVE STABILIZER
A	0.30 or MORE
C	0.29 - 0.20
D	LESS THAN 0.20

A – Acceptable stabilizer loss. Lot is safe for storage until next required retest date.
C – Significant stabilizer loss. Lot does not represent an immediate hazard, but is approaching a potentially hazardous stability condition. This level of stabilizer loss does not adversely affect functioning in a finished round configuration.
D – Unacceptable stabilizer loss. The lot presents a potential safety hazard and is an unacceptable risk for continued storage as bulk propellant, bulk-packed components, or as separate loading propelling charges. The risk of autoignition of propellant in SC-D increases with time. Demilitarization must be completed within **60 days** of notification for bulk propellant, bulk-packed components, and separate loading propelling charges.

- **Observation**: Some M6 propellant storage boxes were not labeled with the manufacturer's propellant lot number and/or the lot number was not readable. Propellants with lost manufacturer lot identity represent a potential safety hazard.

  Recommendation: Develop a local numbering system for any propellant that is not clearly labeled with the manufacturer's lot number. Immediately test this propellant for stabilizer content. Dispose of propellant that is not stable as a first priority, and propellant without a known manufacturer lot number as a second priority. DoD guidance requires disposal within 60 days.

  Reference: Supply Bulletin 742-1, Ammunition Surveillance Procedures, paragraph 13-14, "Lost Lot Identity".

- **Observation**: None of the M6 propellant observed was in its original propellant charge cans.

  Recommendation: Do not download M6 propellant from propellant charge cans into other containers unless final disposition of the material within a year is guaranteed.

- **Observation**: Although the team did not fully investigate the propellant surveillance program being used to monitor the remaining effective stabilizer in the M6 propellant being stored or processed, it appeared that only Ammunition Peculiar Equipment 1995 Near-Infrared Spectroscopy data is being used.

  Recommendation: Develop a propellant surveillance program for the M6 propellants that incorporates recommendations made by Mr. Lewis Kansas, Energetics Materials Analysis Branch, ARDEC, Picatinny Arsenal, in his 20 December 2012 trip report.

  Reference: As stated.

- **Observation**: The preponderance of evidence indicates that the probability of an explosives event directly related to the long-term storage of M6 propellant at Minden is likely. That is: (a) anecdotal evidence indicates that the "kicker boxes" of propellant may contain multiple Lots, instead of the single Lot number indicated on the "blue" labels; (b) due to the unknown storage conditions for M6 propellant after its removal from the propellant charge cans, the propellant's stability cannot be guaranteed; and (c) the bulk packaging (white bag, fiber drum or cardboard box) is not a standard packaging method for long-term storage of M6 propellant. The use of such bulk packaging may (a) not prevent the loss of stabilizer; (b) allow moisture intrusion; and (c) increase nitro-cellulose decomposition rates. These factors, combined with nitro-cellulose's ability to auto ignite, increase the probability of a detonation within a storage structure at Camp Minden within 10 years.

  Recommendation: Aggressively pursue methods to reduce the quantities of the downloaded M6 propellant at Minden to include the use of both controlled open burning and sale. Develop a working group to study unique solutions for the disposal of large quantities of M6 propellant.

  Reference: Supply Bulletin 742-1, Ammunition Surveillance Procedures, paragraph 13-14, "Lost Lot Identity."

Enclosure

12 March 2013

The Adjutant General and Louisiana National Guard Request for Technical Assistance

DEPARTMENTS OF THE ARMY AND AIR FORCE
JOINT FORCE HEADQUARTERS-LOUISIANA
OFFICE OF THE ADJUTANT GENERAL
JACKSON BARRACKS
NEW ORLEANS, LOUISIANA 70117

NGLA-TAG 12 March 2013

MEMORANDUM FOR Assistant Secretary of the Army for Environment, ATTN: DASA-ESOH, Mr. James C. King

SUBJECT: Request for Army Technical Assessment Team

1. Request a Department of the Army Technical Assessment Team to assess stored explosives at Camp Minden, LA. Specifically, request the team conduct an assessment of the potential short and long term hazards associated with the M6 propellant and make recommendations for potential mitigation measures.

2. The M6 propellant is a hazardous material derived from the demilitarization of the M119A2 Propelling Charge by Explo Systems, Inc. ("Explo"), a tenant of the Louisiana Military Department at Camp Minden. The propellant was used in connection with an activity of the DoD as provided in 10 U.S.C. 2692 (b)(1). The excess propellant was produced by Explo under the terms and conditions of its contract with DoD (contract no. W52P1J-10-C-0025). While performing work for the DoD under its contract, Explo illegally and improperly stored large amounts of M6 propellant on the premises of Camp Minden without the knowledge or consent of the State of Louisiana. Explo's actions in this regard violate state and federal law. Explo's illegal activities were discovered by the Louisiana State Police during a routine inspection of their operations. The State of Louisiana has requested assistance from the Department of Defense for the transportation and storage of the excess M6 propellant and is currently awaiting a determination.

3. Point of contact is the undersigned at (318) 613-5313 or email glenn.h.curtis.mil@mail.mil.

Glenn H. Curtis

GLENN H. CURTIS
MG, LAARNG
The Adjutant General

LOUISIANA
NATIONAL GUARD

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
INSTALLATIONS, ENERGY AND ENVIRONMENT
110 ARMY PENTAGON
WASHINGTON DC 20310-0110

20 JUN 2013

MG Glenn H. Curtis
The Adjutant General
Louisiana National Guard
6400 St. Claude Avenue
Jackson Barracks
New Orleans, LA 70117

Dear General Curtis:

Enclosed is the report from the technical assistance visit (TAV) the Army provided 7 - 9 May 2013 at the Louisiana National Guard's (LANG) Camp Minden. The Army provided this TAV as a follow-up to a TAV it had provided on 2 and 3 April 2012 in response to your request of 12 March 2013. The Commander, Camp Minden and Louisiana State Police (LASP) requested this follow-up on 1 May 2013 to assess the potential hazards associated with approximately 130,000 pounds (lbs) of Tritonal that Explo Systems, Inc. (Explo) had stored in Building 1650, and other explosives Explo has in storage at Camp Minden. The attached report provides recommendations LANG and the Louisiana State Police (LASP) may consider to improve the explosives safety posture at Camp Minden.

As requested, the Army's technical assistance team focused its assessment on the hazards associated with the handling and storage of Tritonal in Building 1650 and other explosives Explo stored at Camp Minden. The TAV team did not review Explo's personnel qualifications, operating procedures, and/or its procedures for security or accountability of explosives. LANG may want to consider evaluating these matters.

During this TAV, the TAV team:

a. Assessed the hazards associated with the handling and storage of Tritonal in Building 1650, offered to LANG a demilitarization plan for propellant and explosives generated by Explo, and recommended an approach for establishing a propellant stability program for approximately 15M lbs of M6 propellant remaining at Camp Minden for which lot identity has been lost, pending the final disposition of the M6.

b. Identified some explosives the condition of which posed a serious explosive hazard. As a result, the TAV team recommended LASP, in coordination with LANG, request follow-on technical assistance from an Army Explosive Ordnance Disposal unit. Subsequently, LASP has requested EOD's assistance in assessing the condition of these explosives and recommending to LASP courses of action for LASP to dispose of it safely.

The team that visited Camp Minden remains available to LANG to provide further advice on the Explo materials at Camp Minden. Additionally, the US Army Technical Center for Explosives Safety is a valuable resource for all Army and National Guard activities.

Explosive safety oversight of explosive operations of the nature Explo performed at Camp Minden requires expertise in explosives safety management. Should LANG continue to lease Camp Minden's facilities for operations such as those Explo conducted, I strongly recommend it consider developing this expertise within the Camp Minden staff through attendance at explosive safety training programs the Defense Ammunition Center (DAC) offers. Although some training may require attendance at the DAC, which is located on McAlester Army Ammunition Depot, McAlster, OK, DAC offers many of its course as self-paced, distance-learning courses (see http://ammo.okstate.edu). Additionally, I recommend LANG contact the National Guard Bureau's Senior Quality Assurance Specialist (Ammunition Surveillance), Mr. Clark Combs, to request any assistance it may need to address explosives safety-related matters.

My point of contact for this matter is Mr. J. C. King, Director for Munitions and Chemical Matters, and the Army's Department of Defense Explosives Safety Board Voting Member, at (703) 697-5564; james.c.king4.civ@mail.mil.

Sincerely,

HEWolfe

Hershell E. Wolfe
Deputy Assistant Secretary of the Army
(Environment, Safety and Occupational Health)

Enclosure

Department of Army

Report

of

Explosives Safety Assistance Visit
(7 to 9 May 2013)

to

Louisiana National Guard's
Camp Minden

June 13, 2013

ENCLOSURE

Final Report of Explosives Safety Assistance Visit to Camp Minden (7 to 9 May 2013)

1. Background.

a. On 1 May 2013, COL Ronnie D. Stuckey, Commander, Camp Minden, Louisiana National Guard (LANG) and Lieutenant John Porter, Deputy Command Technician, LA State Police (LASP) requested the Army provide an additional technical assistance visit (TAV) to assess the potential hazards associated with approximately 130,000 pounds (lbs) of Tritonal (80 percent (%) TNT and 20% aluminum powder) stored by Explo Systems, Inc. (Explo) in building 1650 at Camp Minden, LA. LASP and LANG believed these explosives posed a potential explosive hazard to an on-post public traffic route. LASP and LANG requested the TAV also assess other explosives that Explo has in storage at Camp Minden. This was a follow-up to a TAV provided by the Army on 2 and 3 April 2013. The Army provided the report of that visit dated 18 April 2013, to The Adjutant General of the Louisiana National Guard.

b. During 7 to 9 May 2013, a team, under the direction of Mr. James Young, Headquarters, Department of the Army, G-4, conducted the requested TAV. The team consisted of:

- Mr. James Young, Quality Assurance Specialist (Ammunition Surveillance), Department of the Army, G-4
- Mr. James Lane, Defense Ammunition Center (DAC)
- Mr. Russel Ingle, DAC
- Mr. Terry Trivitt, US Army Technical Center for Explosives Safety (USATCES)
- Mr. Paul Cummins, USATCES

2. Executive Summary.

a. As requested, this TAV team assessed the hazards associated with the handling and storage of Tritonal in building 1650, offered to the LANG a demilitarization plan for propellant and explosives generated by Explo, and recommended an approach for establishing a propellant stability program for approximately 15M lbs of M6 propellant remaining at Camp Minden for which lot identity has been lost, pending the final disposition of the M6.

b. The TAV team observed additional explosives that Explo had in storage beyond the M6 propellant addressed by the initial TAV, which was conducted 2 and 3 April 2013, and the Tritonal in building 1650. The Tritonal in building 1650 was the primary subject of this TAV. Recommendations to address the potential explosive hazards associated with these additional observations are made below. The total quantity of Explo explosive material the TAV team observed at Camp Minden included:

- 128 lbs of Black Powder
- 200 lbs of Composition H6

- 4 50-gallon drums of Ammonium perchlorate
- 2 50-gallon drums and 150-lb boxes Explosive D (ammonium picrate)
- 109,000 lbs of M30 Propellant
- 320,000 lbs of Clean Burning Incendiary (CBI)
- 661,000 lbs of Nitrocellulose
- 1.817M lbs of Tritonal, mixed with tar
- 15M lbs of M6 propellant

c. The recommendations from both the initial TAV (conducted 2 and 3 April 2013), which focused on the explosive safety hazards posed by approximately 18M lbs of M6 propellant, and this TAV were offered to LASP and LANG for consideration for reducing the potential explosive hazards posed to the public by Explo's operations. On 20 May 2013, the Commander, Camp Minden informed the Army that effective 1200 hrs, on 20 May 2013, Explo-related public safety issues had been resolved, and LASP had revoked Explo's explosive license pending resolution of criminal charges.

Observations and Recommendations

Building 1650

Observation: The only building on Camp Minden's S-line that continues to store Explo's explosives is building 1650. This is a metal structure containing approximately 130,000 lbs of Tritonal (80% TNT and 20% aluminum powder, with some tar contamination). The Tritonal in this building is contained in palletized, cardboard boxes. The explosives safety quantity distance arcs from this building extend over 3rd Avenue, which is an on-post road that is used as a local school bus route; therefore, it is considered a public traffic route. LASP and LANG consider this a public safety issue. The TAV team agreed this public exposure poses a potential catastrophic risk that should be addressed.

Recommendation: The TAV team believes, based on its observations and the condition of this Tritonal, that this Tritonal is safe to handle, transport, and store in its current configuration on post. However, some boxes may need to be re-palletized. The TAV surveyed 20 earth-covered magazines during the course of its review and identified storage space appropriate for the Tritonal currently in building 1650. The TAV team recommends the Tritonal be re-warehoused to the earth-covered magazines identified, as soon as possible. Once this is accomplished, the potential explosives safety hazards on the S-Line in building 1650, which are of concern to the LASP and LANG, will be eliminated. This will be a significant accomplishment to reduce public risk.

Disposition of M6 Propellant and other Explosives

Observation: The TAV team surveyed an area for burning explosives (potential burning ground), primarily the M6 propellant. This area, which is next to Camp Minden's E-Line, could be used for open burning (treatment) of propellants (Hazard Classification {HC} 1.3) and potentially for explosives (e.g., Tritonal), which are HC 1.1, and explosive-contaminated material (e.g., red water). (See Figure 1.)

Recommendation: The TAV team recommends (a) vegetation be cleared in and around the potential burning grounds; (b) access to areas to be used for burn pans, staging and explosives handling, and to the storage area for support material and equipment be improved; (c) crushed rock be added throughout the burning grounds; and (d) a personnel operating structure be sited outside of K-24 for the crew's use during burns. The TAV team also recommends consideration be given to installing barrier material to minimize potential environmental contamination due to residues from treatment of propellant and other materials. Applicable environmental requirements under federal, state and local laws pertaining to waste storage, treatment, and disposal operations involving burning, including permitting, which are not otherwise discussed in this report, should be addressed by the LANG. The burning grounds may be sited to accommodate 10 burn pans, each capable of holding up to 4,000 pounds of propellant per burn. Assuming LANG could conduct 2 burns of up to 80,000 lbs per day, the remaining M6 propellant (approximately 15M pounds) might be destroyed in less than a year.

Propellant Burning Operations

Observation: Open burning of propellant and other explosives is an extremely hazardous operation that requires a comprehensive explosives safety management program (ESMP).

Recommendation: If LANG decides to conduct these burning operations, the TAV team recommends LANG or LASP begin planning for the equipment and support needed for this operation. To assist in planning, the TAV recommends LANG and/or LASP consider the actions listed below prior to conducting burning operations.

- Determine the ownership of the materials to be disposed, and LANG's or LASP's authority to dispose of these materials.
- Seek the assistance needed, if any, to carry out the recommended actions.
- Coordinate with environmental regulators and obtain environmental permits, if any, required by applicable federal, state, or local laws or regulations.
- Develop:
  - Burning ground site safety plan.
  - Standing Operating Procedures.
  - Qualifications and responsibilities or tasks for the personnel involved (e.g., supervisor, technical support, surveillance personnel).
  - Procedures for physical security and access control that are required to ensure worker and public safety.
  - Spill response plan.
- Fabricate burn pans and equipment required to load propellants into the burn pans.
- Clear vegetation, conduct surface improvements and any required construction.
- Establish and site an operating building for the crew's use during burning operations.
- Determine the:
  - Type of firefighting equipment needed on site, and coordinate with local medical and fire departments for contingency support.
  - Tools, Material Handling Equipment, and personnel protective equipment (PPE) required for the conduct of operations.
  - Electrical support, including grounding systems, required for safe operations.
  - Federal, state, or local regulatory requirements that may apply to closure of the burning grounds after these operations are complete.

- Plan and implement solid and hazardous waste (e.g., ash) collection, sampling and disposal procedures.

M6 Propellant Stability

Observation: Low stability content can result in auto-ignition of propellant in storage, causing a detonation. At Camp Minden, Explo's operations appear to have resulted in the loss of lot identity for the M6 propellant that Explo has in storage. Explo's packaging configurations (e.g., incorrect lot markings on containers and outer-packs, multiple markings); storage procedures, which exposed some of the packaged propellant to the environment; and packaging process, which may have mixed lots led the TAV team to conclude that lot identity was, at a minimum, questionable. Explo did not have a propellant stability monitoring program in place. Although the transfer of M6 propellant to earth-covered storage has reduced the risk to public safety, an explosive event (i.e., a detonation) from auto-ignition is very possible without a propellant stability monitoring program in place to track the propellant's stabilizer content and address potentially unstable propellant.

Recommendation: The TAV team recommends a plan for establishing a propellant stability monitoring program at Camp Minden be developed. The potential risks associated with the continued storage of propellant should be conveyed to all concerned, including commercial contractors located on Camp Minden. The TAV team also recommends LANG seek the assistance it needs, if any, to develop this plan.

Other Matters:

- **Observation:** The TAV team surveyed 20 earth-covered magazines, operating buildings, and the Super Critical Water Oxidation (SCWO) operating building. Explo reportedly was developing the SCWO under a sub-contract with General Atomics. In addition to the M6 propellant and Tritanol, Explo had in storage: Explosive D (ammonium picrate); Composition H6; black powder; M30 propellant; nitrocellulose in water (marked ATK-Radford AAA), and clean burning incendiary (CBI). Explo stored M6 propellant in 3 configurations: 880 lb sacks, 110 lb drums, and 32 lb cardboard boxes. These materials are discussed in other observations below and quantities are summarized here.

  Recommendation: Based on the condition and known hazards associated with the above mentioned explosives, the TAV team recommends disposal of this material in the order of priority indicated below. The recommended method of treatment is also provided.

  - Explosive D in drums, which may have crystallized, making it more sensitive, should be disposed of as soon as practical. (LASP has requested Army Explosive Ordnance Disposal (EOD) assistance in assessing the condition of these explosives and recommending to LASP courses of action for LASP to dispose of it safely.) Quantity: 2 50-gal drums (1 metal, 1 plastic) and 3 50-lb boxes.

- Ammonium perchlorate, which may have crystallized, making it more sensitive, should be disposed. Quantity: 4 50-gal drums (plastic).
- SCWO influent, unknown quantity or composition. Quantity: several 16 oz bottles and a large tank.
- Black powder, nitrocellulose, in water and CBI – destroy by burning. (Quantity: 128 lbs of black powder, 661,000 lbs of nitrocellulose, and 320,000 lbs of CBI).
- M30 Propellant – destroy by burning. Quantity: 109K lbs.
- Composition M6 Propellant – commercial sales or, if necessary, destroy by burning. Quantity: 15M lbs.
- Tritonal – destroy by burning or open detonation. Quantity: 1.817M lbs.
- Composition H6 – destroy by burning or open detonation. Quantity: 200 lbs.

- **Observation:** Building 1619 contains equipment for demilitarizing 750 lb bombs including equipment for melting out explosives and flaking Composition H6. This equipment and material, which is heavily contaminated with explosives residues, includes: autoclaves, kettles, re-melter, flaker belts, pumps, piping, rails, and platforms. In addition, the building that housed this operation is heavily contaminated. Among other contamination, the TAV team observed explosive-contaminated fixtures, sprinkler systems, walls, floors, and ceilings.

  Recommendation: The TAV team recommends LANG explore the feasibility of decontaminating; disassembling, with additional decontamination, as required; and disposal of explosive-contaminated material that cannot be decontaminated. The TAV team also recommended LANG seek the assistance it needs, if any, to develop a plan for decontaminating this explosive-contaminated material.

- **Observation:** Approximately 200 lbs of Composition H6 is in building 1619 near the Composition H6 flaking operation.

  Recommendation: The TAV team recommends LANG prepare a plan for collecting and packaging the explosives left in this building and moving it to earth-covered storage.

- **Observation:** Inside building 1619 (between the 750 lb bomb demilitarization operation and Composition H6 flaker belts) is a hazardous waste storage area holding with 3, 50-pound boxes of Explosive D.

  Recommendation: These explosives are recommended to be disposed as waste in coordination with the appropriate regulatory agency. (LASP has requested Army EOD assistance in assessing the condition of these explosives and recommending to LASP courses of action for LASP to dispose of it safely.)

- **Observation:** The SCWO is not operational, but four drums of ammonium perchlorate mixed with water and two drums of ammonium picrate (Explosive D) mixed with water, which were used as feedstock for the SCWO, remain.

  Recommendation: These drums are recommended to be disposed as waste, in coordination with the appropriate regulatory agency. (LASP has requested Army EOD assistance in assessing the condition of these explosives and recommending to LASP courses of action for LASP to dispose of it safely.)

- **Observation:** There are two large effluent tanks in the SCWO building that contain unknown material. According to Explo personnel, these tanks only contain iron oxide in water, and were reportedly tested by Toxicity Characteristics Leaching Procedure (TCLP) analysis.

  Recommendation: Ownership and responsibility for SCWO-related materials should be determined by the LANG. LANG may coordinate with the owner to arrange for suitable chemical analysis and seek the material's proper disposal in compliance with applicable federal and state laws.

- **Observation:** A refrigerator in the SCWO building contains several 16oz plastic containers of test influent that was intended as input for the SCWO.

  Recommendation: LANG may coordinate with the material's owner to arrange for suitable chemical analysis and then seek the materials proper disposal in compliance with applicable federal and state laws. (LASP has requested Army EOD assistance in assessing the condition of these explosives and recommending to LASP courses of action for LASP to dispose of it safely.)

- **Observation:** A large stainless steel tank in the SCWO building contains an unknown chemical influent intended as input for the SCWO. This container potentially contains Explosive D and/or ammonium perchlorate.

  Recommendation: This container should not be moved, handled, or its contents removed until its contents are analyzed and identified, and proper disposition is determined. LANG may coordinate with the material's owner to arrange for suitable chemical analysis and proper disposal in compliance with applicable federal and state laws.

- **Observation:** The TAV team recommends that safety clearance zones near the E-line be established for the potential burning grounds.

  Recommendation: Figure 1 (below) depicts the safety clearance zones the TAV team recommends for the burning grounds. With the recommended safety clearance, the burning grounds should be able to accommodate safely 10 burn pans, each one capable of holding up to 4,000 pounds of propellant.

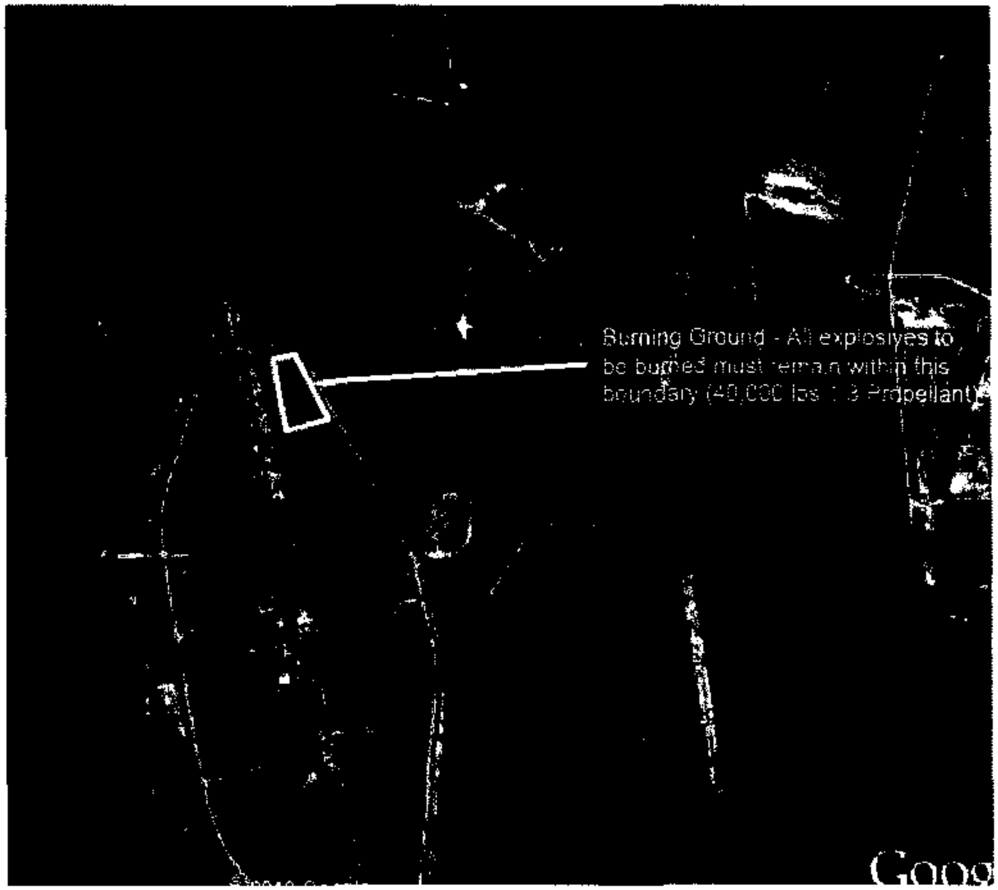

Burning Ground - All explosives to be burned must remain within this boundary (40,000 lbs 1.3 Propellant)

Figure 1

TARGET SHEET

SITE NAME: CAMP MINDEN\EXPLO SYSTEMS INC

CERCLIS I.D.: LAR000072223

TITLE OF DOC.: ATTACHMENT 1 - ENFORCEMENT ATTACHMENT

DATE OF DOC.: 03/18/2015

NO. OF PGS. THIS TARGET SHEET REPLACES: 3

SDMS #: 1175422 **KEYWORD:** 93.04

SENSITIVE ?	X	**MISSING PAGES ?**	
ALTERN. MEDIA ?		**CROSS REFERENCE ?**	

LAB DOCUMENT ?		**LAB NAME:**	
ASC./BOX #:			
CASE #:		**SDG #:**	

COMMENTS : THIS TARGET SHEET IS IN PLACE OF ATTACHMENT 11. ATTACHMENT 11 DOES NOT EXIST, IT WAS REFERENCED IN ERROR IN THE AMENDED ACTION MEMO.

004475

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

23 FEB 2015

MG Glenn H. Curtis
The Adjutant General
Louisiana National Guard
6400 St. Claude Avenue
Jackson Barracks
New Orleans, LA 70117

Dear General Curtis:

Enclosed is the report from the technical assistance visit (TAV) you requested in your letter of July 2, 2014 regarding an assessment of the potential short- and long-term hazards associated with the storage of M6 propellant. The attached TAV report provides recommendations for the Louisiana Military Department's (LMD) and the U.S. Environmental Protection Agency, Region 6's (EPA 6) consideration for implementation to improve the explosives safety posture at the Louisiana National Guard's (LANG) Camp Minden.

An Army team conducted the requested TAV at Camp Minden from 1 to 5 December 2015. The TAV team reviewed explosives safety issues related to the continued storage of M6, to include current storage configurations. During the TAV, the team also reviewed and discussed with LMD and representatives from EPA 6, and the Louisiana State Police, LMD's plans for execution of the removal action outlined in the 28 October 2014 Administrative Settlement Agreement and Order on Consent for Removal Action (AOC).

As during previous TAV, the team's primary focus was on ensuring recommendations it made for LMD's consideration focused on actions that would reduce or mitigate potential explosive hazards to LMD personnel and public safety. Among other matters, the team also made explosives safety recommendations for consideration to improve the efficiency of and reduce the operational risk associated with the proposed removal action.

My point of contact for this matter is Mr. J. C. King, Director for Munitions and Chemical Matters, and Army DDESB Voting Member, phone number (703) 697-5564; email jc.king@us.army.mil.

Sincerely,

HEWolfe

Hershell E. Wolfe
Deputy Assistant Secretary of the Army
(Environment, Safety and Occupational Health)

Enclosure: As stated.

Department of Army

Report

of

Explosives Safety Assistance Visit (1 to 5 December 2014)

to

Louisiana National Guard's Camp Minden

February 23, 2015

ENCLOSURE

Final Report of Explosives Safety Assistance Visit to Camp Minden (1 to 5 December 2014)

1. Background

a. On 2 July 2014, Major General Glenn H. Curtis, The Adjutant General, Louisiana National Guard requested the Army provide a Technical Assistance Visit (TAV) within the next 30 days to Camp Minden, Louisiana, to assess the potential short and long term hazards associated with the continued storage of M6 propellant (approximately 15 million pounds) and other energetic material (certain ignitable material), and provide recommendations relative to the risk of explosion presented by the current storage configuration. The Environmental Protection Agency (EPA) made a similar request on June 24, 2014.

b. On 29 September 2014, the Secretary of the Army authorized the Assistant Secretary of the Army for Installation, Energy and the Environment (ASA (IE&E)), to provide the technical assistance and advice required to address the explosives safety concerns potentially posed by certain ignitable material at Camp Minden, Louisiana. The Secretary of the Army's authorization allowed the Army's technical assistance to: (1) include on-site visits to assess the condition of the material; (2) provide advice on how to establish a stability monitoring program; (3) provide recommendations to ensure the explosives safety of operations; (4) include technical reviews of plans; and (5) provide advice related to the storage and final disposition of this material. The Secretary also allowed the ASA (IE&E) to request other Army organizations to assist in providing this support and re-delegate this authority, as determined necessary.

c. The Army's provision of support was delayed until completion of negotiations and agreement on a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Settlement Agreement, the subject of which was this ignitable material.

d. During 1 to 4 December 2014, a team, under the direction of Mr. J. C. King, Director for Munitions and Chemical Matters, Office of the Deputy Assistant Secretary of the Army for Environment, Safety; and Dr. Upton Shimp, Director, Defense Ammunition Center (DAC) and U.S. Army Technical Center for Explosives Safety (USATCES), conducted the requested TAV. The team consisted of:

- Mr. J. C. King
- Dr. Upton Shimp, DAC/USATCES
- Mr. Paul Cummins, USATCES
- Mr. Ray Mitchell, DAC
- Dr. Robert Kirgan, U.S. Army Environmental Command

2. Executive Summary

a. As requested, the TAV team observed the condition of the material as currently stored within several magazines; visited both the primary proposed demolition (open burn) area and a secondary or alternate burn area; observed a test burn of approximately 1,200 pounds of M6, with air monitoring; and reviewed and discussed EPA's and the Louisiana Military Department's (LMD) proposed approach for the conduct of operations. The TAV team also reviewed the draft Statement of Work (SOW) that LMD would release seeking proposals for the work required.

b. The TAV team provided advisory input to LMD and EPA pertaining to the lack of a propellant stability monitoring program for the M6 in storage at Camp Minden with LMD and EPA 6. The current status of the propellant's stability is not known; therefore, determination of the risk of an auto ignition is not possible. Analysis of the propellant LOTS present at Camp Minden in April 2013 indicated a propellant stability program should be established as soon as possible. Given the information available at that time, the Army believed the loss of knowledge about the propellant's stability was not immediately problematic, but after 18 to 24 months the risk posed would increase significantly. TAV teams recognized that the timeline over which the risk would become significant was uncertain given the manner in which this propellant was handled; packaged, including a loss of LOT identity; and stored, including outside storage with exposure to weather. The TAV team agreed with EPA 6 that a propellant stability monitoring program would at best provide only a relative idea of the propellant's stability. This was truer for the 800-lbs bag configurations than the other configurations. Given the packaging configurations of the M6 (800-lb bags, 110-lb drums, and 50-lb cardboard boxes), the TAV team discussed the need to give priority, in order, to the destruction of the 800-lb bags, then the 110-lb drums, and then the boxes. The TAV team believes it may be possible to determine, with confidence, the stability of propellant in the 50-lb boxes, possibly allowing some of this propellant to be reclassified to reusable product. Doing so could be challenging, but it could reduce the quantity of M6 that needs to be burned. Although it may be possible to test the propellant concurrently with other required actions, the process could not be initiated until after the other packaging configurations are removed from storage. The TAV team cautioned about unnecessary handling of the packaged propellant, regardless of configuration and recommended the propellant only be handled once (i.e., moved directly from storage to final disposition and limiting re-warehousing within a storage structure to that absolutely required for safety.

c. The TAV team cautioned against the aggressive nature of the proposed schedule for the destruction of the M6 propellant, emphasizing that open burning of propellant is a hazardous operation. As such, an operation of this nature with multiple burn pans and high quantities of propellants requires a comprehensive explosives safety management program (ESMP), careful orchestration of required activities, and careful oversight.

Observations and Recommendations

Disposition of M6 Propellant and other Explosives

Observations

- The aggressive timeline established by EPA 6 for the demilitarization of M6 and CBI may add unnecessary risk to an already hazardous operation.
- LMD and EPA Region 6's (EPA 6) On-Scene Coordinator (OSC) appeared to understand the:
  - Explosives hazards involved in the proposed disposal activity;
  - Measures required to manage the safe disposal of M6 and CBI at Camp Minden;
  - Actions needed to mitigate risk to workers and the public; and
  - Environmental monitoring requirements needed to help ensure public safety.
- As written, the SOW required adherence to DoDM 4145.26, Contractor Safety Manual (see below), with burn pan spacing of 150 ft.

> "C15.9.8. Parallel beds of explosives prepared for burning shall be separated by not less than 150 ft [46 m]. Care shall be taken to prevent material igniting from smoldering residue or from heat retained in the ground from previous burning operations. Unless a burned-over plot has been saturated with water and passed a safety inspection, 24 hours shall elapse before the next burning."

Recommendations - LMD and EPA 6 should consider:

- Allowing for additional time for the disposal of M6, but ensuring operations were completed as quickly and safely as reasonably possible to reduce the potential for auto ignition of propellant for which the stability is unknown.
- Ensuring the selected contractor provide and implement a comprehensive explosives safety management program (ESMP) for each of the activities required to dispose of the propellant and CMI.
- Reviewing the personnel qualifications required for operating personnel contained in the SOW.
- Changing the 150-ft distance requirements of DoDM 4145.26 that were established for burns of mixed explosives material and are probably excessive for burns of propellant only. (An Army activity that is permitted for open burn of propellants, with a DDESB-approved explosives safety site plan uses a 50-ft spacing for propellant-only burns.)

Propellant Burning Operations

Observations

- The proposed burning ground was a satisfactory location for use as a burning ground; could accommodate placement of burn pans, possibly as many as 40. The number of pans that would fit would be dependent on the pans' size and the separation distance required. The size of the pans should allow the propellant to be spread out to a depth of no more than 3 inches.
- An alternate or secondary burning ground, although significantly smaller, was a satisfactory location for use as a burning ground. This site, which is further away from the installations border and populated areas than the primary site, could accommodate placement of burn pans, possibly as many as 10. The number of pans would be dependent on their size and the separation distance required. The size of the pans should allow the propellant to be spread to a depth of no more than 3 inches.
- The proposed burning ground site and the alternate burn ground sites are located in areas that should comply with DoD explosives safety quantity-distance requirements.
- The alternate site is located very near storage structures storing significant quantities of propellant. Use of this area, concurrently with the primary burning grounds would:
  - Reduce, significantly, the distance required to transport propellant, particularly the 800 lbs bags, stored near this site to the primary burning ground.
  - Allow the net explosives weight (NEW) of the total quantity of propellant in storage to be quickly and safely reduced.
  - Allow for the site's continued use, if determined necessary, to continue to burn propellant stored at the other side of the installation.
- The test burn of 1,200 pounds was successfully executed.
- The video of the burn showed propellant grain kick out, and post-burn examination of the burn area confirmed propellant kick out to approximately 10 ft.
- The smoke plume from the burn was not observed because there was not a clear line-of-sight from the observation point.
- The monitoring instrument used was pre-checked; however, the results were not available prior to the team's departure.
- The 800-lb bag packaging has a releasable hopper chute on the bottom and should facilitate direct unloading into the burn pan.

Recommendations - LMD and EPA 6 should consider

- Requiring the contractor to:
  - Provide a comprehensive work plan and standing operating procedures for each operation to be performed.
  - Provide a burn ground layout that:
    - ✓ Provides for the safety of personnel handling (e.g., loading pans) and conducting other operations at the site.
    - ✓ Provides for the required separation of each burn plan.
    - ✓ Allows for transport ingress and egress.
  - Detail the test procedures to be used, including monitoring.
  - Outline the training required for personnel.
  - Outline plans for loading burn plans. Such plans should consider:
    - ✓ Unloading the 800-lb bags of M6 into a burn pan using the bag's hopper chute.
    - ✓ Loading burn pans in a manner that simplifies operations and handling (e.g., one 800-lb bag per pan), without being concerned with the amount actually loaded.
  - Schedule and conduct a pre-operational walkthrough prior to conducting full scale operations.
  - Present a detailed plan for electrical grounding and static discharge control, to include periodic electrical test of the grounding systems.
  - Outline plans for remediating the burn site or sites used upon completion of burning operations.
- Developing operational parameters for burns based on weather conditions, population centers, and plume modeling.
- Requiring the contractor to establish and operate two burn area (one at the primary site and one at the alternate site.

M6 Propellant Storage Configurations

Observations

- Earth-covered storage magazines were dry and structurally sound.
- There was no visual or olfactory indication (i.e., a sour nitrous smell of decomposing propellant would indicate an auto ignition could occur in less than 60 days) of an immediate near-term risk of propellant auto-ignition.
- Storage configurations of packaged M6 propellant varied:
  - 800-lb hopper bags some directly on wooden pallets, with some placed inside a tri-wall cardboard box on a wooden pallet. Some of the tri-wall boxes had been weakened by exposure to weather (rain, heat) when stored outside.
  - 110-lb fiberboard drums
  - 50-lb boxes.

- Damaged packaging and opened containers (bags, drums [crushed], and boxes) were present in most structures visited, with small spills of propellant evident.
- Unstable stacks most likely caused by hasty storage, excessive stack height, and weathered and collapsing packaging were present in most structures.
  - Actions taken by LMD, LA State Police and EPA 6 to mitigate unstable stacks appeared effective
  - Moving the propellant within a storage structure and from storage for its final disposition will be challenging and require development of standing operating procedures to ensure the safety of the crews uploading the propellant.
- Some storage locations have rail only access, with access complicated by brush and overgrowth and by the height of the rail. Other structures are within what appears to be wetland. Movement of propellant-loaded pallets to transport vehicles may require use of movable ramps or construction of a ramp or avenue (path) for access.

Recommendations - LMD and EPA 6 should consider

- Ensuring the contractor develops and implements standing operating procedures for:
  - Handling and moving propellant within storage structures, including addressing lose propellant found on floors and pallets; and to transport vehicles
  - Loading and securing propellant on transport vehicles; and offloading propellant at the burn grounds
- Ensuring the contractor provides increased operator supervision, control, and safety oversight during the handling, movement, and loading of propellant within storage structures.
- Ensuring the contractors plans and procedures that minimize the handling and movement of propellants.
- Providing priority, in order, to the disposal of propellant in 800-lb bags, the 110-lb fiberboard drums, and the 50-lbs boxes.
- Requiring the contractor to remove vegetation from storage site and prepare storage sites, as required, for moving propellant from storage to transport vehicles.

Transportation of Propellant to Burn Areas

Observation

- Storage area roads were gravel.
- Primary transport roads were paved and in good condition.

- Speed limits and marked transportation routes, if followed, can reduce mishap potential.

Recommendation - LMD and EPA 6 should consider

- Establishing speed limits based on hazard analysis of driver experience and road conditions for transportation routes.
- Ensuring that routes used for transporting propellants from storage areas to the burning areas are maintained
- Prohibiting public and limiting authorized traffic on routes used for transporting propellants during transport.

Other Matters

Observation: Potential for M6 propellant auto-ignition will increase over time. Eventually, risk of auto-ignition will increase exponentially. Specific deterioration rate for the M6 at Minden cannot reliably be predicted due to: lost LOT identity; storage in unsealed packaging; and previous exposure to the elements while stored outside.

Recommendation - LMD and EPA 6 should consider

- Proceeding with the expeditious, safe disposal of M6 propellant in the priority stated above.
- Determining whether the stability of boxed or fiberboard drums of propellant can be returned to usable product and re-establishing a propellant stability for such until it is disposed of either by burning or sale.

Exhibit E

Louisiana State Police
Hazardous Materials Incident Report

HAZARDOUS MATERIALS INCIDENT REPORT

Louisiana State Police
Transportation and Environmental Safety Section

Incident #	06-05324		Officer	S. Hopkins				Troop	G	Region	II
Occurred Date	8/24/2006	Time	0830	Enforcement	MCSAP		RTK		Number		
Notified Date	8/24/2006	Time	0854	Parish	Webster						
10-97 Date	8/24/2006	Time	0900	Incident Location	Louisiana Army Ammunition Plant, Doyline, LA						
10-8 Date	8/29/2006	Time	1800								

SHIPPER / FACILITY INFORMATION

Shipper / Facility	Explo Systems Inc						
Address	1702 Fourth Street	City	Minden	State	LA	Zip	71055
Representative	David Smith	Title	Vice President	Telephone	318-382-8700		

CARRIER INFORMATION

Carrier Information							
Address		City		State		Zip	
Representative		Title		Telephone			

DRIVER INFORMATION

Driver/Operators Name									
Address		City		State		Zip			
Drivers Lic #		State		Class		DOB		Telephone	

INCIDENT TYPE / CONTAINER TYPE

	Highway		Air		Water		Rail		Bottle, Pail, Bag		Storage Tank		Container		Cylinder		Drum
X	Fixed Site		Pipeline	X	Explosive				Intermodal Tank		Portable Tank		Tank Truck		Barge, Vessel		Rail Car
	Investigation		Other						Totes	X	Other	Industrial Facility					

Chemical Involved	Tritonal	Amount	unknown	Amount Lost	

AGENCIES ON SCENE

	Local		State		Federal	Name		Rep	
	Local		State	X	Federal	Name	BATFE	Rep	
	Local	X	State		Federal	Name	LA National Guard	Rep	
X	Local		State		Federal	Name	Webster Parish Sheriffs Office	Rep	
	Local		State		Federal	Name		Rep	

HIGHWAYS CLOSED

Highway #	I-20	Time Closed	0910	Time Opened	1445
Highway #	US 80; LA 164; Goodwill Rd;	Time Closed	0910	Time Opened	0930 8/25/06

PROTECTIVE ACTION

	Shelter in Place	x	Evacuation	x	Road Closure		None	X	Impacted Area
	Injuries		Fatalities		Initial Field Investigation		Follow-up Field Investigation	X	Photographs		Video

WEATHER CONDITIONS

Temperature		Wind Speed	mph	Direction		Humidity	

REMEDIATION/MUTUAL AID RESPONSE

On Scene	UXB International Inc	Rep	Jim Tomiko	Telephone	703-724-9600
On Scene		Rep		Telephone	

004486

HAZARDOUS MATERIALS INCIDENT ENFORCEMENT

VIOLATIONS

No.	Regulation	Unit	Out of Service	Description of Violation	Responsible Party	Penalty
1						
2						
3						
4						
5						
6						
7						
8						

Initial Review		Final Review		Attachments	() YES () NO	Photographs	() YES () NO

VEHICLE OUT OF SERVICE: As provided in Chapter 12 of L.R.S. line 52, the unit(s) designated above is (are) hereby declared OUT OF SERVICE at: 1823 Elton Road, Jennings
Until all noted OUT OF SERVICE (O/S) violations are corrected

ATTACHMENTS

	MSDS Information		*Notification Procedures*		*LEPC Notification Information*
X	*Site Photographs*		*Meteorological Information*		*Facility Investigative Documents*
	Facility Monitoring Data		*Employee Interviews*	x	*Facility Drawings or Blueprints*

REVIEWED

Approval		*Date*		*Approval*		*Date*	

INCIDENT DETAILS

Revised KRS 11/4/02

On 8/24/2006 at 0900 hours Officer Hopkins was notified by Sgt Bobbitt of a fire and detonation of the Explo Systems manufacturing facility located on E-Line on the Louisiana Army Ammunition Plant (LAAP) in Minden. Initial reports included multiple detonations and fires involving all of the E-line manufacturing plant including two trailers each containing 48 Bombs, 750 pound, GP, M117 located at the north receiving dock of E-line. Initial calculation of explosive weight at the dock was 36,480 pounds. The hazard area was calculated to be 2.1 miles, which included I-20; LA 80; LA 164; Goodwill Road; Town of Doyline; and all areas of the Ammo Plant. At 1000 hours evacuation began and roads were closed.

An incident command post was set up at the intersection of Goodwill Road and LA Hwy 80.

At 1330 an aerial reconnaissance was conducted by Officer Hopkins and Lt Viator. Recon revealed all of the buildings containing explosives had burned down. Small fires were still burning in numerous locations in and out of the fenced perimeter of E-line. No evidence of a large quantity of unexploded bombs massed in one area was visible.

Explo Systems employees revised the estimated number of bombs located at the loading dock to be 26 each. Based on the reconnaissance and this estimate, the hazard area was reduced to 1.5 miles. This revision allowed I-20 to be reopened but all other previously closed highways remained closed. All previously evacuated facilities remained closed. Because of the numerous fires, a ground reconnaissance was scheduled for 0700, 8/25/2006.

At 0715 hours, 8/25/2006, a ground reconnaissance was conducted by State Police Hazmat and COL Stuckey, LAAP commander. Ground recon concluded there were no large quantities of unexploded bombs in any one location. Numerous unexploded bombs were scattered about the facility. Based on the fragmentation range of one unexploded bomb, the hazard area was reduced to 1400 yards. This reduction allowed all evacuees to return. The incident command post was moved to the intersection of 4th Street and McArthur Ave.

On 8/27/06, UXB International personnel arrived on scene to assess the damage and prepare for site cleanup. An assessment of E-line and the surrounding area indicated a sweep outside the perimeter fence should be conducted for a distance of 1000 feet around the north end and a

distance of 500 feet around the south end of the perimeter fence. The recovery of fully loaded bombs was to be accomplished first. The priority of operations was to clear the north end of the exclusion area outside the perimeter fence, then the south end of the exclusion area outside the perimeter fence, then the inside areas of the perimeter fence. This would allow the exclusion area to be reduced as quickly as possible allowing workers back into the areas.
Cleanup operations began on Monday, 8/28/06. By 1800 hours the north areas outside the perimeter fence had been searched and bomb recover was started. By Tuesday 8/29/06 at 1800 hours all areas had been searched for explosive materials and all fully loaded bombs had been transported to magazines for storage. The 1400 yard hazard area was removed and the incident command post was removed. All areas outside the fenced perimeter of E-line were opened. UXB personnel began recovery of loose energetic material inside the perimeter on 8/30/06 and continue at the time of this report.

Further investigation revealed the following information.

Bombs were brought from a magazine to the north receiving dock of E-line by truck. The bombs were moved into building 1726 where they received scores in the steel surface of the bomb by a remotely operated lathe. The bomb was then moved to a press where the 3 bomb sections were broken apart. The nose and tail were taken back to the dock to load onto a trailer. The center section was placed in another press where the explosives were pressed out of the steel case. The empty steel center section was stored in building 1726 until moved to a burn pad on another site on LAAP for burning off the explosive residue. The explosives from the center section were taken to the trailer with the nose and tail sections. When the trailer was full it was taken to Building 1719.

At Building 1719 the nose section, tail section and bulk explosives from the center section, were taken to the third floor where they were placed on the pre-melters. Pre-melters used steam heat to heat the explosives to 220 degrees. When the explosives on the pre-melter become liquid, they drain off through pipes to the 2nd floor where they are collected into kettles. There 4 kettles, one pre-melter fills one kettle. In the kettle the explosives are heated and the aluminum settles to the bottom of the kettle and the melted tnt is sent to the flaker where it is cooled and flaked into it's final state. Flaked tnt is boxed and sent to Building 1712 for transport to storage magazines.

On the morning of the fire, the reported quantity of explosives was 15000 pounds of flaked tnt in Building 1712; 10000 pounds of melted tnt in Building 1719; 8000 pounds of bulk explosive in Building 1724; and 36000 pounds net explosive weight in 96 bombs at the loading ramp of Building 1726.

An interview of Explo Systems employee [redacted], [redacted], [redacted], Gibsland, LA [redacted] DOB: [redacted], telephone [redacted], was conducted on 8/31/06 at 1500 hours. [redacted] stated he worked for Explo Systems as lead man in the pre-melt room located on the third floor of building 1719. [redacted] stated he has worked at LAAP on various lines for a number of years. He supervised one other employee that morning, [redacted]. The pre-melt room contained 4 pre-melters. Bomb components and explosives were on pre-melters 3 and 4. Kettle 4 had approximately 6000 and kettle 3 had approximately 3000. Kettle 1 and 2 were empty. [redacted] stated they didn't normally start the flaking process until both kettle 3 and 4 were full at 6000 pounds each. During [redacted] shift, he was responsible for filling kettle 1 and 2 and the previous night shift was responsible for filling kettle 3 and 4. [redacted] stated he moved the material being melted off pre-melter 4 onto pre-melter 3 to fill the partially full kettle 3. He then began cleaning pre-melter 1 and 2. [redacted] stated cleaning pre-melters consisted of using a stainless steel tool to rake the residue, aluminum and tnt, from the grate that the explosives sit on while melting. Both pre-melter 1 and 2 were not being used but had liquid tnt in them. [redacted] stated he had finished pre-melter 1 and was working on pre-melter 2 when he observed smoke coming from under the grate of pre-melter 1. He stated he went to look at the smoke and observed a flame inside the pre-melter. [redacted] stated he sent his helper to notify the other employees while he left the area.

The fire spread from Building 1719 to other buildings on E-line by traveling the wood hallways that linked the buildings together. The only building linked by hallways that was not burned was building 1714. A section of the wooden hallway had been replaced with metal roofing and siding creating an effective fire break.

Exhibit E

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Hazardous Materials Incident Report

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Transportation and Environmental Safety Section

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AGENCIES ON SCENE

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	Local	X	State		Federal	Name	LA National Guard	Rep	
X	Local		State		Federal	Name	Webster Parish Sheriffs Office	Rep	
	Local		State		Federal	Name		Rep	

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Temperature		Wind Speed	mph	Direction		Humidity	

REMEDIATION/MUTUAL AID RESPONSE

On Scene	UXB International Inc	Rep	Jim Tomiko	Telephone	703-724-9600
On Scene		Rep		Telephone	

004490

HAZARDOUS MATERIALS INCIDENT ENFORCEMENT

VIOLATIONS

No.	Regulation	Unit	Out of Service	Description of Violation	Responsible Party	Penalty
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2						
3						
4						
5						
6						
7						
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Approval		*Date*		*Approval*		*Date*	

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Action Memo Photos
Explo Systems, Camp Minden, LA

Photo 1: M6 Propellant improperly stored outside by Explo

Photo 2: M6 Propellant scattered on the ground (after October 2012 explosion)

Photo 3: Result of explosion of magazine storing black powder and tractor trailers storing M6 Propellant in October 2012

Action Memo Photos
Explo Systems, Camp Minden, LA

Photo 4: Example of explosive storage magazine at Camp Minden

Photo 5: Trees growing on top of explosive storage magazine at Camp Minden

Photo 6: M6 propellant and Aluminum/TNT/Tritonal stored in explosive storage magazine at Camp Minden

Photo 6: Nitrocellulose stored in explosive storage magazine at Camp Minden

004498

M6 Propellant Photos
Explo Systems, Camp Minden, LA

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Photo 3: Result of explosion of magazine storing black powder and tractor trailers storing M6 Propellant in October 2012

M6 Propellant Photos
Explo Systems, Camp Minden, LA

Photo 4: Example of explosive storage magazine at Camp Minden

Photo 5: Trees growing on top of explosive storage magazine at Camp Minden

Photo 6: M6 propellant and Aluminum/TNT/Tritonal stored in explosive storage magazine at Camp Minden

Photo 6: Nitrocellulose stored in explosive storage magazine at Camp Minden

M6 Propellant Photos
Explo Systems, Camp Minden, LA

Photo 7: M6 Propellant spilled outside magazines exposed to elements

Photo 8: M119A2 155MM Propelling Charge provided to Explo by US Army for demilitarization; Origin of M6 Propellant

Photo 9: M6 propellant spilled on floor at S-Line (common throughout facility)

M6 Propellant Photos
Explo Systems, Camp Minden, LA

Photo 10: Result of explosion of magazine storing black powder and tractor trailers storing M6 Propellant in October 2012

Photo 11: Storage of M6 Propellant outside at Explo

Photo 12: M6 and Tritonal/Aluminum/TNT containers falling and spilling contents inside magazines


1.1D
1.1D


004504


OVERPACK
POWDER, SMOKELESS
UN0161

004508


OVERPACK
POWDER, SMOKELESS
UN0161

004510

004511

004512

004513


C
Type 4
450

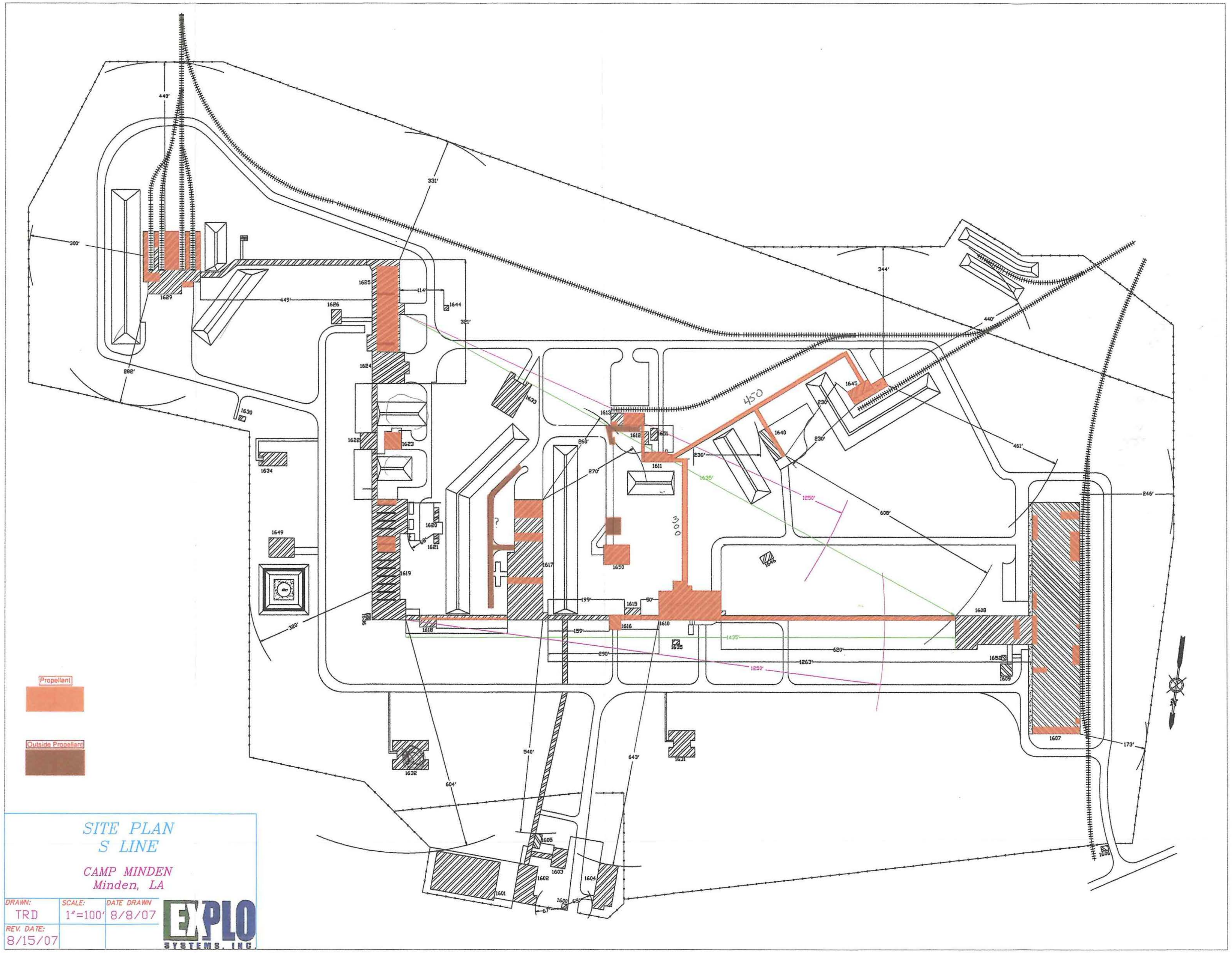

TYPE
WEIGHT

004517


ATK
59.0

004520

004521


Propellant
Outside Propellant
SITE PLAN
S LINE
CAMP MINDEN
Minden, LA
DRAWN:
TRD
SCALE:
1"=100'
DATE DRAWN
8/8/07
REV. DATE:
8/15/07
EXPLO
SYSTEMS, INC.

004524

004528


TYPE 4

004530

004532


EUR

L-1				
BLDG #	**ITEM DISCRIPTION**	**# OF SKIDS**	**WEIGHT**	**TOTAL**
2234	M-6 PROPELLANT ((880lb Bulk)	107	94,160	94,160
125,000				
2249	M-6 PROPELLANT ((880lb Bulk)	142	124,960	124,960
125,000				
2250	M-6 PROPELLANT ((880lb Bulk)	142	124,960	124,960
125,000				

L-2				5/21/2013
BLDG #	**ITEM DISCRIPTION**	**# OF SKIDS**	**WEIGHT**	**TOTAL**
RAIL LINE				
2401	M-6 PROPELLANT (60LbX36bX)	79	170,640	
300,000	" " (880lb BULK BX)	86	75,680	246,320
2402	M-6 PROPELLANT (60LbX36bX)	111	239,760	**239,760**
300,000				
2462	NITROCELLULOSE (METAL BRLS)	631	93,388	
300,000	" (FB BRLS)	15	2,250	95,638
2403	M-6 PROPELLANT (60LbX36bX)	79	170,640	
300,000	(880ib Bulk)	82	72,160	242,800
2463	NITROCELLULOSE (METAL BRLS)	292	67,160	67,160
300,000	FLAMMABLE SOLID	81.5	146,700	146,700
2404	M-6 PROPELLANT (140lbx6)	148	124,320	124,320
300,000				
2405	M-6 PROPELLANT (880lb BULK BOX)	141	124,080	124,080
300,000				
2464	**EMPTY**	0	0	0
125,000	BUILDING DESTROYED			
2406	M-6 PROPELLANT (880lb BULK BOX)	137	120,560	120,560
300,000				
2407	M-6 PROPELLANT (60lb bxX36)	64	138,240	
300,000	(880lb Bulk)	114	100,320	238,560
2465	NITROCELLULOSE (METAL BRLS)	1,004	139,556	139,556
300,000	139lbs per brl			
2408	M-6 PROPELLANT (880lb BULK BOX)	166	146,080	146,080
300,000				
2409	M-6 PROPELLANT (880lb BULK BOX)	165	145,200	145,200
300,000				
2466	NITROCELLULOSE (METAL BRLS)	1,052	155,696	155,696
300,000	148lbs per brl			
2410	M-6 PROPELLANT (60LbX36bX)	74	159,840	
300,000	" " (880lb BULK BX)	48	42,240	**202,080**

L-2				5/21/2013
BLDG #	ITEM DISCRIPTION	# OF SKIDS	WEIGHT	TOTAL
1ST ROAD				
2411	M-6 PROPELLANT (880 Lb Bulk)	141	124,080	124,080
125,000				
2467	M-6 PROPELLANT (880 Lb Bulk)	142	124,960	124,960
125,000				
2412	FLAMMABLE SOLIDS	145	261,000	261,000
125,000				
2468	FLAMMABLE SOLIDS	141	253,800	253,800
125,000	M-6 PROPELLANT (880 Lb Bulk)	118	103,840	103,840
2413	M-6 PROPELLANT (880 Lb Bulk)	142	124,960	124,960
125,000				
2414	M-6 PROPELLANT (100lb brlx6)	5	3,000	
300,000	" " (121lb brlx6)	1	726	
	" " (140lb brlx6)	279	234,360	238,086
2415	M-6 PROPELLANT(60lbx36)	39	84,240	
125,000	" " (880lb BULK BX)	44	38,720	122,960
2469	M-6 PROPELLANT (100lb brlX6)	30	18,000	
125,000	" " (121lb brlX6)	4	2,904	
	" " (140lb brlX4)	58	32,480	
	" " (140lb brlX6)	85	71,400	124,784
	TYPE 2	264	117,534	
	TYPE 7	2 bx	102	
	TYPE 9	1	336	
	TYPE 14	1.5	222	
	TYPE 15	1.5	538	
2416	M-6 PROPELLANT(60lbx36)	25	54,000	
125,000	" " (880lb BULK BX)	80	70,400	124,400
2417	M-6 PROPELLANT (60lb bxX36)	116	250,560	
300,000	" " (880lb BULK BX)	42	36,960	287,520
2418	M-6 PROPELLANT (880lb BULK bx)	166	146,080	146,080
300,000				
2419	CBI (MAXED OUT)	105	120,960	120,960
125,000				
2470	FLAMMABLE SOLID	88	158,400	158,400
125,000	M-6 PROPELLANT (880 Lb Bulk)	142	124,960	124,960
2420	M-6 PROPELLANT(60lbx36)	25	54,000	
125,000	" " (880lb BULK BX)	80	70,400	124,400

L-2				5/21/2013
BLDG #	ITEM DISCRIPTION	# OF SKIDS	WEIGHT	TOTAL
2ND ROAD				
2421	M-30 PROPELLANT	138	109,200	
300,000	M-6 PROPELLANT (140lb brlX6)	57	47,880	
	" " (880Lb Bulk)	45	39,600	196,680
2422	M-6 PROPELLANT (880 Lb Bulk)	154	135,520	135,520
300,000				
2423	M-6 PROPELLANT(60lbx36)	25	54,000	
125,000	" " (880lb BULK BX)	80	70,400	124,400
2471	CBI	91	85,594	
125,000	M-6 PROPELLANT (880 Lb Bulk)	40	35,200	
	BLACK POWDER	1	128	
	AMMONIUM PICRATE	1	140	
	M-6 PROPELLANT (140Lb X 6Brls)	6	5,149	
	" " (Shot Bags)	8	6,400	132,611
2424	M-6 PROPELLANT (880lb BULK bx)	142	124,960	124,960
125,000				
2425	M-6 PROPELLANT (880LB Bulk)	142	124,960	124,960
125,000				
2472	FLAMMABLE SOLID	137	246,300	246,300
125,000	M-6 PROPELLANT (880LB Bulk)	141	124,080	124,080
2426	M-6 PROPELLANT (880LB Bulk)	142	124,960	124,960
125,000				
2473	FLAMMABLE SOLID	123	221,400	221,400
125,000	M-6 PROPELLANT (880LB Bulk)	110	96,800	96,800
2427	M-6 PROPELLANT (880 Lb Bulk)	142	124,960	124,960
125,000				
2474	M-6 PROPELLANT (140lb brlX6)	40	33,600	
125,000	" " (880 Lb Bulk)	102	89,760	
	" " (140Lbx6Brls for ship>	84	70,560	193,920
2428	M-6 PROPELLANT (121lb brlX6)	86	62,436	
125,000	" " (140lb brlX4)	38	21,280	
	" " (140lb brlX6)	49	41,160	124,876
	TYPE 2	24	12,796	
	TYPE 7	1	50	
	TYPE 15	6	2,258	
2429	M-6 PROPELLANT (60lb X 36bx)	120	259,200	**259,200**
300,000				
2430	M-6 PROPELLANT (140lb brlX6)	205	172,200	
300,000	" " (140lb brX4)	42	23,520	
	" " (880lb BULK BX)	29	25,520	221,240

L-2				5/21/2013
BLDG #	ITEM DISCRIPTION	# OF SKIDS	WEIGHT	TOTAL
3RD ROAD				
2431	M-6 PROPELLANT (60lbx36)	25	54,000	
125,000	" " (880lb BULK BX)	80	70,400	124,400
2475	FLAMMABLE SOLID	122	219,600	219,600
125,000	M-6 PROPELLANT (140lb brlX6)	63	52,920	
	" " (60lbX36bx)	33	71,280	
	" " (140Lbx6Brl for ship)	47	39,480	163,680
2432	CBI	99+9bx	114,336	114,336
125,000				
2433	M-6 PROPELLANT (880LB Bulk)	142	124,960	124,960
125,000				
2476	FLAMMABLE SOLID	30	54,000	54,000
125,000	M-6 PROPELLANT (880lb bulk bx)	142	124,960	124,960
2434	M-6 PROPELLANT (140lb/121LBX6)	116	85,000	
125,000	" " (880lb BULK BX)	45	39,600	124,600
2435	M-6 PROPELLANT (140lb brlX6)	198	166,320	166,320
300,000				
2436	M-6 PROPELLANT (60lb bxX36)	126	272,160	
300,000	" " (880lb BULK BX)	31	27,280	299,440
2437	M-6 PROPELLANT (140lb brlX6)	286	240,240	240,240
300,000				

L-2				5/21/2013
BLDG #	**ITEM DISCRIPTION**	**# OF SKIDS**	**WEIGHT**	**TOTAL**
4TH ROAD				
2438	M-6 PROPELLANT (880LB Bulk)	142	124,960	124,960
125,000				
2477	FLAMMABLE SOLID	142	255,600	255,600
125,000	M-6 PROPELLANT (60lb X 36bx)	14	30,240	
	" " (880lb bulk bx)	97	85,360	115,600
2439	M-6 PROPELLANT (100lb brlX6)	12	7,200	
125,000	" " (120lb brlX6)	6	4,320	
	" " (121lb brlX6)	105	76,230	
	" " (140lb brlX4)	24	13,440	
	" " (140lb brlX6)	28	23,520	124,710
2440	M-6 PROPELLANT (60lbx36)	25	54,000	
125,000	" " (880lb BULK BX)	80	70,400	124,400
2478	M-6 PROPELLANT (880lb BULK BX)	185	162,800	
125,000	" " (120LbX6Brls)	2	1,440	
	" " (121LbX6Brls)	1	726	
	" " (140LbX4Brls)	69	38,640	203,606
2441	M-6 PROPELLANT (880lb bulk bx)	142	124,960	124,960
125,000				
2442	M-6 PROPELLANT (880lb bulk bx)	166	146,080	146,080
300,000				
2443	M-6 PROPELLANT (60lb bxX36)	49	116,424	
300,000	" " (100lb brlX6)	1	600	
	" " <121lb brX6>	3	2,178	
	" " (140lb brlX4)	2	1,120	
	" " (140lb brlX6)	115	96,600	216,922

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L-3				
BLDG #	ITEM DISCRIPTION	# OF SKIDS	WEIGHT	TOTAL
1st Rd				
2301	M-6 PROPELLANT (60lb X 36bx)	72	155,520	
300,000	" " (880lb Bulk	82	72,160	227,680
2302	M-6 PROPELLANT ((880lb Bulk)	165	145,200	145,200
300,000				
2303	M-6 PROPELLANT (60lb X 36bx)	79	170,640	
300,000	" " (880lb Bulk	82	72,160	242,800
2304	M-6 PROPELLANT (60lb X 36bx)	77	166,320	
300,000	" " (880lb Bulk	82	72,160	238,480
2306	M-6 PROPELLANT (140lbX6Brl)	289	242,760	**242,760**
300,000				
2308	M-6 PROPELLANT (60lb X 36bx)	78	168,480	
300,000	" " (880lb Bulk	82	72,160	240,640
2310	M-6 PROPELLANT (140lbX6Brl)	64	53,760	
125,000	" " (880lb Bulk	80	70,400	124,160
2311	M-6 PROPELLANT (60lb X 36bx)	109	235,440	
300,000	" " (880lb Bulk	20	17,600	253,040
2312	M-6 PROPELLANT (60lb X 36bx)	120	259,200	**259,200**
300,000				

L-3				
BLDG #	**ITEM DISCRIPTION**	**# OF SKIDS**	**WEIGHT**	**TOTAL**
2nd Rd				
2317	**M-6 PROPELLANT** (100LbX6Brls)	26	15,600	
300,000	" " (121LbX6Brls)	19	13,794	
	" " (140LbX6Brls)	185	155,400	184,794
2318	M-6 PROPELLANT (140lbX6Brl)	235	197,400	**197,400**
300,000	**FLAMMABLE SOLID**	45	20,700	20,700
2319	**M-6 PROPELLANT** (60lb X 36bx)	25	54,000	
125,000	" " (880lb Bulk	80	70,400	124,400
2361	M-6 PROPELLANT	95	79,800	**79,800**
125,000	NITROCELLULOSE		200,380	**200,380**
2320	**M-6 PROPELLANT** (60lb X 36bx)	25	53,640	1 lite skid
125,000	" " (880lb Bulk	80	70,400	124,040
2362	**FLAMMABLE SOLID**	404	234,750	234,750
125,000				
2321	**M-6 PROPELLANT** (60lb X 36bx)	25	54,000	
125,000	" " (880lb Bulk	80	70,400	124,400

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L-3				
BLDG #	**ITEM DISCRIPTION**	**# OF SKIDS**	**WEIGHT**	**TOTAL**
3rd Rd				
2322	M-6 PROPELLANT (60lb X 36bx)	78	168,480	
300,000	" " (880lb Bulk	83	73,040	241,520
2323	M-6 PROPELLANT (60lb X 36bx)	135	291,600	291,600
300,000				
2324	M-6 PROPELLANT (140lbX6Brl)	252	204,480	204,480
300,000				
2325	M-6 PROPELLANT (60lb X 36bx)	78	168,480	
300,000	" " (880lb Bulk	84	73,920	242,400
2326	M-6 PROPELLANT (140lbX6Brl)	242	203,280	203,280
300,000				
2327	M-6 PROPELLANT (140lbX6Brl)	259	217,560	217,560
300,000				
2328	M-6 PROPELLANT (140Lb X 6)	54	45,360	
125,000	" " (880lb Bulk	90	79,200	124,560
2363	M-6 PROPELLANT (880 Bulk Bags)	142	124,960	124,960
125,000				
2329	M-6 PROPELLANT (140lbX6Brl)	148	124,320	124,320
125,000				
2364	FLAMMABLE SOLID	82	147,044	147,044
125,000	M-6 PROPELLANT (880 Bulk Bags)	142	124,960	124,960

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L-4				
BLDG #	ITEM DISCRIPTION	# OF SKIDS	WEIGHT	TOTAL
501	M-6 PROPELLANT (60lb X 36bx)	136	293,760	293,760
300,000				
502	M-6 PROPELLANT (60lb X 36bx)	136	293,760	
300,000	" " (880lb Bulk	6	5,280	299,040
503	M-6 PROPELLANT (60lb X 36bx)	137	295,920	
300,000	" " (880lb Bulk	4	3,520	299,440
504	M-6 PROPELLANT (60lb X 36bx)	80	172,800	
300,000	" " (880lb Bulk	89	78,320	251,120
505	M-6 PROPELLANT (60lb X 36bx)	80	172,800	
300,000	" " (880lb Bulk	99	87,120	259,920
506	M-6 PROPELLANT (60lb X 36bx)	132	285,120	
300,000	" " (880lb Bulk	16	14,080	299,200
507	M-6 PROPELLANT (60lb X 36bx)	136	293,760	
300,000	" " (880lb Bulk	6	5,280	299,040
508	M-6 PROPELLANT (60lb X 36bx)	138	298,080	298,080
300,000				
509	M-6 PROPELLANT (60lb X 36bx)	137	295,920	295,920
300,000				