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# Phase I Final Rule and Technical Development Document of Uniform National Discharge Standards (UNDS)

## Gas Turbine Water Wash: Nature of Discharge

April 1999

# NATURE OF DISCHARGE REPORT

***Gas Turbine Water Wash***

## 1.0 INTRODUCTION

The National Defense Authorization Act of 1996 amended Section 312 of the Federal Water Pollution Control Act (also known as the Clean Water Act (CWA)) to require that the Secretary of Defense and the Administrator of the Environmental Protection Agency (EPA) develop uniform national discharge standards (UNDS) for vessels of the Armed Forces for "...discharges, other than sewage, incidental to normal operation of a vessel of the Armed Forces, ..." [Section 312(n)(1)]. UNDS is being developed in three phases. The first phase (which this report supports), will determine which discharges will be required to be controlled by marine pollution control devices (MPCDs)—either equipment or management practices. The second phase will develop MPCD performance standards. The final phase will determine the design, construction, installation, and use of MPCDs.

A nature of discharge (NOD) report has been prepared for each of the discharges that has been identified as a candidate for regulation under UNDS. The NOD reports were developed based on information obtained from the technical community within the Navy and other branches of the Armed Forces with vessels potentially subject to UNDS, from information available in existing technical reports and documentation, and, when required, from data obtained from discharge samples that were collected under the UNDS program.

The purpose of the NOD report is to describe the discharge in detail, including the system that produces the discharge, the equipment involved, the constituents released to the environment, and the current practice, if any, to prevent or minimize environmental effects. Where existing process information is insufficient to characterize the discharge, the NOD report provides the results of additional sampling or other data gathered on the discharge. Based on the above information, the NOD report describes how the estimated constituent concentrations and mass loading to the environment were determined. Finally, the NOD report assesses the potential for environmental effect. The NOD report contains sections on: Discharge Description, Discharge Characteristics, Nature of Discharge Analysis, Conclusions, and Data Sources and References.

## 2.0 DISCHARGE DESCRIPTION

This section describes the gas turbine water wash and includes information on: the equipment that is used and its operation (Section 2.1), general description of the constituents of the discharge (Section 2.2), and the vessels that produce this discharge (Section 2.3).

### 2.1 Equipment Description and Operation

Shipboard gas turbine systems are used on certain vessels to provide propulsion power, provide initial mechanical starting power for large gas turbine propulsion systems, and to generate electricity. Power is generated by combusting fuel in a “gas generator” (commonly referred to as a “combustor”). The combustor exhaust gas rotates the “power turbine,” providing the mechanical energy to either drive a propulsion shaft, start a larger turbine, or generate electricity.[1]

Over extended periods of operation, residual lubrication oil and hydrocarbon combustion by-product deposits can form on gas turbine internals. Since naval vessels operate in a marine environment, salt water introduced with intake air can also lead to salt deposits on the gas turbine internals. Washing the gas turbine internals periodically with a solution of freshwater and cleaning compound maintains operating efficiency and prevents corrosion of the metallic components. The cleaning compound that is currently used for this purpose is a petroleum-based solvent referred to as “gas path cleaner.”[1]

Two types of water wash systems exist on vessels with gas turbines. One is a dedicated “hard-piped” system; the other type requires manual attachment of a hose to a hot water source and placement of the other hose end into the turbine plenum. Both of these systems are designed to introduce water wash into the turbine housing while the turbine starter motor is slowly rotated, (i.e., cranked without combustion). The hard-piped system includes a rinse tank where distilled/demineralized water and cleaning compound are mixed. The contents of the tank are sprayed into the gas turbine under pressure, either by using a pump or by pressurizing the tank with compressed air.[1] Immediately following the wash, the engine is sprayed with water.

Gas turbine engines are enclosed in a “module” with floor drains designed to remove minor leakage of fuel and synthetic lube oil that may occur during normal turbine operation. The floor drains also remove any water wash introduced into the turbine that is not discharged to the atmosphere. Water wash from external scrubbing of the gas turbine also flows to these floor drains. Inadvertent spills of synthetic lube oil that occasionally occur during turbine maintenance activities are potentially capable of entering the drains; however, standard procedure is for ship personnel to immediately contain and wipe up any spillage that occurs.[1]

On most Navy ships, gas turbine water wash effluent and any drainage of residual material from leaks and spills are collected and held in a dedicated tank system for shore disposal. The Navy refers to this system as the “Gas Turbine Waste Drain Collecting System.” The dedicated system includes a centrifugal pump and piping to transfer the water wash to a hose connection topside. A hose is used to transfer the water wash to a pierside collection facility. On vessels without this system, the drainage is discharged to the environment as a component of other UNDS discharges (i.e., Surface Vessel Bilgewater/OWS, Welldeck, and Deck Runoff).[1]

The wash water effluent discharge from U.S. Coast Guard (USCG) vessel gas turbine washing operations is to the bilge, from where it is processed as bilgewater (along with other bilgewater contributors) through the shipboard OWS prior to overboard discharge. The gas turbine water wash effluent for USCG vessels is addressed as a component of the Surface Vessel Bilgewater/OWS Discharge NOD Report.

Gas turbine propulsion engines are also used aboard Navy landing craft air cushion (LCAC) amphibious landing crafts. Two gas turbine auxiliary power units (APUs) are also installed on LCACs to provide starter air. The LCAC gas turbine washwater discharge is addressed as a component of the Welldeck Discharges NOD Report.

Water wash cleaning of aircraft gas turbine engines aboard an aircraft carrier is addressed as a component of the Deck Runoff NOD Report.

### 2.2 Releases to the Environment

The water wash introduced into Navy propulsion turbines contains water and solvent-based gas path cleaner. The discharge could be expected to contain components of the cleaner, oil and grease (O&G), petroleum-derived fuel and lubricant constituents, synthetic lubricating oil, constituents introduced into the turbine system with the incoming sea air, hydrocarbon combustion by-products, and metals leached from gas turbine components. On most gas turbine Navy and MSC ships, gas turbine washwater is collected in a dedicated tank and not discharged overboard within 12 n.m. On ships without a dedicated collecting tank, this discharge is a component of deck Runoff, welldeck runoff, or bilgewater as described in the previous section.

### 2.3 Vessels Producing the Discharge

Table 1 lists the vessel classes that have shipboard gas turbine systems. Vessel classes equipped with a Gas Turbine Waste Drain Collecting System are denoted in Table 1. For the other vessel classes listed in Table 1, the gas turbine water wash is discharged as a component of another UNDS discharge. The maximum number of vessels with Gas Turbine Waste Drain Collecting System is 127. Army and Air Force vessels do not have gas turbine engines and do not generate this discharge.

## 3.0 DISCHARGE CHARACTERISTICS

This section contains qualitative and quantitative information that characterizes the discharge. Section 3.1 describes where the discharge occurs with respect to harbors and near-shore areas, Section 3.2 describes the rate of the discharge, Section 3.3 lists the constituents in the discharge, and Section 3.4 gives the concentrations of the constituents in the discharge.

### 3.1 Locality

Vessels with Gas Turbine Waste Drain Collecting Systems collect and store drainage from normal turbine operations and water wash effluent for pierside disposal. On most gas turbine Navy and MSC ships, gas turbine washwater is collected in a dedicated collecting tank and not discharged overboard within 12 n.m. On ships without a dedicated collecting tank, this discharge is a component of deck Runoff, welldeck runoff, or bilgewater as described in the previous section.

### 3.2 Rate

Available information on gas turbine water wash usage rates is contained in gas turbine design and operations and maintenance documentation.[2,3,4] The frequency of water wash cleanings and the quantity of water wash consumed per washing event is different between USCG, Navy, and Military Sealift Command (MSC) vessels.

Navy and MSC vessel gas turbines used for propulsion are washed after each 48 hours of operation or at least once per month.[5] Two gallons of the gas path cleaner are initially mixed with 38 gallons of distilled/demineralized water. Immediately following the wash, the turbine is spray rinsed with 80 gallons of water. An additional 2 gallons of detergent/water mixture is used to clean external turbine surfaces, as necessary. Each cleaning of the propulsion turbines produces 122 gallons of water wash. Therefore a vessel with four propulsion gas turbines each cleaned once every 48 hours of operation would generate an average of 244 gallons of water wash per day.

### 3.3 Constituents

The chemicals used in gas turbine operation and maintenance that could potentially contribute to contamination of turbine water wash are gas path cleaner, Naval distillate fuel F-76, gas turbine fuel, JP-5, synthetic lube oil, copper, cadmium, and nickel.[6-10]

The gas path cleaners used by the Navy include petroleum distillates (aromatic and aliphatic hydrocarbons), assorted glycols, detergents, soaps, and water.[6,7] The composition of one such cleaner used by the Navy can be found in its material safety data sheet (MSDS).[6] According to the MSDS sheet, the cleaner can contain the aromatic hydrocarbon naphthalene at concentrations of up to 3.9%. Other petroleum distillate hydrocarbon constituents that could be present include aliphatic volatile organic compounds and other semivolatile compounds that are priority pollutants. The priority pollutants that are potential constituents of gas turbine water wash are cadmium, copper, nickel, and naphthalene. None of the constituents is a bioaccumulator.

### 3.4 Concentrations

The addition of gas path cleaner containing 3.9% naphthalene to the wash water at a 2% gas path cleaner concentration yields an estimated water wash naphthalene concentration of 800 milligrams per liter (mg/L). The following shows this calculation.

Naphthalene Concentration (mg/L) =
(% of cleaner in water)(% of naphthalene in cleaner)(density of naphthalene)
where,
% of cleaner in water = 2
% of naphthalene in cleaner = 3.9
density of naphthalene = (1.0253 g/cm$^3$)(1000 mg/g)(1000 cm$^3$/L) = 1.025 * 10$^6$ mg/L

Naphthalene Concentration = (0.02)(0.039)(1.025 * 10$^6$) = 800 mg/L

Because naphthalene is a semivolatile organic compound that is not expected to volatilize while the water wash is sprayed into the turbine, the maximum water wash effluent naphthalene concentration is also estimated at 800 mg/L. Other constituents are variable and were not estimated.

## 4.0 NATURE OF DISCHARGE ANALYSIS

Based on the discharge characteristics presented in Section 3.0, the nature of the discharge and its potential impact on the environment can be evaluated. The estimated mass loadings are presented in Section 4.1. In Section 4.2, the concentrations of discharge constituents after release to the environment are estimated and compared with the water quality criteria. In Section 4.3, the potential for the transfer of non-indigenous species is discussed.

### 4.1 Mass Loadings

The water wash volume estimate for a Navy ship propulsion turbine cleaning operation and naphthalene concentration estimate of 800 mg/L were used to estimate the maximum annual mass loading. The estimate is based on the assumption that one turbine cleaning for each vessel is performed each day within 12 n.m.

Mass Loading of Naphthalene (lbs/yr) =
(naphthalene conc.)(discharge vol.)(365 days/yr)(# vessels) (3.7854 L/gal) (2.2 lb/kg) (10$^{-6}$ kg/mg)

(800 mg/L)(244 gal/day)(365 days/yr)(127)(3.7854 L/gal)(2.2 lb/kg)(10$^{-6}$ kg/mg) = 75,400 lbs/yr

The mass loading of O&G that can be introduced into the water wash effluent from within the gas turbine depends on (a) the amount of residue present; and (b) the degree to which the water wash spray removes the residue as it passes through the turbine.

### 4.2 Environmental Concentrations

Table 2 shows that the estimated naphthalene concentration exceeds the most stringent state water quality criteria (WQC) for naphthalene. Concentrations of oil and grease are expected to exceed WQC because the source of this discharge (gas turbine cleaning) is designed to dissolve fuel, lubricant, and other hydrocarbon deposits.

### 4.3 Potential for Introducing Non-Indigenous Species

There is no potential of introduction, transport, or release of non-indigenous species between different geographical areas, because the water wash system does not use seawater and therefore does not involve the discharge of seawater originating in another geographical region.

## 5.0 CONCLUSIONS

If discharged, gas turbine water wash has the potential to cause an adverse environmental effect within 12 n.m. because:

1) Estimated concentrations of naphthalene exceed and the most stringent state WQC and the mass loading of this priority pollutant would be significant; and

2) Concentrations of oil and grease are expected to be significant because the source of this discharge (gas turbine cleaning) is designed to dissolve fuel, lubricants and other deposits.

## 6.0 DATA SOURCES AND REFERENCES

To characterize this discharge, information from the following sources was obtained to develop this NOD report. Table 3 shows the sources of data used to develop this NOD report.

**<u>Specific References</u>**


1. UNDS Equipment Expert Meeting Minutes. June, 20, 1997.

2. Uniform Maintenance Procedure Card (MPC), WAGB 400 Main Gas Turbine, MPC M-C-062, Amendment 3.

3. Uniform Maintenance Procedure Card (MPC), WHEC 378 Main Gas Turbine, MPC M-C-017, Amendment 0.

4. Uniform Maintenance Procedure Card (MPC), WHEC 378 Emergency Generator, MPC A-W-001, Amendment 0.

5. Maintenance Requirement Card (MRC), OPNAV 4790 (Rev. 2-82).

6. Gas Path Cleaner Material Safety Data Sheet, supplied by M. Galecki of DDG 51 Flight Upgrade Office via facsimile to Malcolm Pirnie (C. Geiling) on June 12, 1997.

7. Military Specification MIL-C-85704, "Cleaning Compound, Turbine Engine Gas Path".

8 Military Specification MIL-F-16884, "Fuel, Naval Distillate".

9. Military Specification MIL-F-5624, "Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-

10. Military Specification MIL-L-23699, "Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number 0-156".

**General References**

USEPA. Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B). 40 CFR Part 131.36.

USEPA. Interim Final Rule. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance – Revision of Metals Criteria. 60 FR 22230. May 4, 1995.

USEPA. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants. 57 FR 60848. December 22, 1992.

USEPA. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California, Proposed Rule under 40 CFR Part 131, Federal Register, Vol. 62, Number 150. August 5, 1997.

Connecticut. Department of Environmental Protection. Water Quality Standards. Surface Water Quality Standards Effective April 8, 1997.

Florida. Department of Environmental Protection. Surface Water Quality Standards, Chapter 62-302. Effective December 26, 1996.

Georgia Final Regulations. Chapter 391-3-6, Water Quality Control, as provided by The Bureau of National Affairs, Inc., 1996.

Hawaii. Hawaiian Water Quality Standards. Section 11, Chapter 54 of the State Code.

Mississippi. Water Quality Criteria for Intrastate, Interstate and Coastal Waters. Mississippi Department of Environmental Quality, Office of Pollution Control. Adopted November 16, 1995.

New Jersey Final Regulations. Surface Water Quality Standards, Section 7:9B-1, as provided by

The Bureau of National Affairs, Inc., 1996.

Texas. Texas Surface Water Quality Standards, Sections 307.2 - 307.10. Texas Natural Resource Conservation Commission. Effective July 13, 1995.

Virginia. Water Quality Standards. Chapter 260, Virginia Administrative Code (VAC) , 9 VAC 25-260.

Washington. Water Quality Standards for Surface Waters of the State of Washington. Chapter 173-201A, Washington Administrative Code (WAC).

Committee Print Number 95-30 of the Committee on Public Works and Transportation of the House of Representatives, Table 1.

The Water Quality Guidance for the Great Lakes System, Table 6A. Volume 60 Federal Register, p. 15366. March 23, 1995.

**Table 1. Vessels With Gas Turbine Systems**

| Branch | Class | No. | Vessel Type | Comment |
|---|---|---|---|---|
| Navy | AOE 6 | 3 | Fast Combat Support Ship | Dedicated collection system |
| | CG 47 | 27 | Guided Missile Cruiser | Dedicated collection system |
| | DD 963 | 31 | Destroyer | Dedicated collection system |
| | DDG 51 | 18 | Guided Missile Destroyer | Dedicated collection system |
| | DDG 993 | 4 | Guided Missile Destroyer | Dedicated collection system |
| | FFG 7 | 43 | Guided Missile Frigate | Dedicated collection system |
| | MCM 1 | 14 | Mine Countermeasure Vessel | Unknown configuration |
| MSC | T-AKR 310 | 1 | Fast Sealift Ship | Dedicated collection system |
| USCG | WAGB 399 | 2 | Icebreaker | Discharged to bilge |
| | WHEC 378 | 12 | High Endurance Cutter | Discharged to bilge |

No. = number of vessels in class

**Table 2. Comparison of Gas Turbine Water Wash Estimated Concentration and Water Quality Criteria (μg/L)**

| Constituent | Maximum Estimated Concentration | Federal Acute WQC | Most Stringent State Acute WQC |
|---|---|---|---|
| Naphthalene | 800,000 | None | 780 (HI) |

Notes:
Where historical data were not reported as dissolved or total, the metals concentrations were compared to the most stringent (dissolved or total) state water quality criteria.

HI = Hawaii

**Table 3. Data Sources**

| NOD Section | Data Source | | | |
|---|---|---|---|---|
| | Reported | Sampling | Estimated | Equipment Expert |
| 2.1 Equipment Description and Operation | Equipment Literature | | | X |
| 2.2 Releases to the Environment | OPNAVINST 5090.1B | | | X |
| 2.3 Vessels Producing the Discharge | UNDS Database | | | X |
| 3.1 Locality | | | | X |
| 3.2 Rate | Standard Operating Procedures | | X | X |
| 3.3 Constituents | MSDS | | X | X |
| 3.4 Concentrations | MSDS | | X | |
| 4.1 Mass Loadings | | | X | |
| 4.2 Environmental Concentrations | | | X | |
| 4.3 Potential for Introducing Non-Indigenous Species | | | | X |