

**Emission Factor Documentation for AP-42
Section 10.8**

Wood Preserving

Final Report

**For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group**

EPA Purchase Order No. 8D-1933-NANX

MRI Project No. 4945

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Research Triangle Park, NC 27711**

Attn: Mr. Dallas Safriet (MD-14)

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NOTICE

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PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA). The work was begun under Contract No 68-D2-0159, and completed under EPA Purchase Order No. 8D-1933-NANX (MRI Project No. 4945). Mr. Dallas Safriet was the requester of the work.

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EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 10.8
Wood Preserving

1. INTRODUCTION

The document *Compilation of Air Pollutant Emission Factors* (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 10.8, Wood Preserving.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the wood preserving industry. It includes a characterization of the industry, a description of the different process operations, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection (and emission measurement) procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details how the new AP-42 section was developed. It includes the review of specific data sets and a description of how candidate emission factors were developed. Section 5 presents the AP-42 Section 10.8, Wood Preserving.

2. INDUSTRY DESCRIPTION¹⁻³

Wood preservation is the pressure or thermal impregnation of chemicals into wood to provide effective long-term resistance to attack by fungi, bacteria, insects, and marine borers. By extending the service life of timber products by five to ten times, wood preservation reduces the need for harvest of already stressed forestry resources, reduces operating costs in industries such as utilities and railroads, and ensures safe working conditions where timbers are used as support structures.

Wood preserving facilities fall under Standard Industrial Classification (SIC) code 2491, Wood Preserving. This classification includes establishments primarily engaged in treating wood, sawed or planed in other establishments, with creosote, pentachlorophenol, or inorganic preservatives to prevent decay and to protect against fire and insects. Wood preserving facilities fall under the six-digit Source Classification Code (SCC) 307005. Table 2-1 lists the SCC's for wood preserving.

2.1 CHARACTERIZATION OF THE INDUSTRY³

In 1995, the 451 wood preserving plants operating in the United States produced a total of 16,404,000 cubic meters (m³) (578,874,000 cubic feet [ft³]) of treated wood. The Southeast and South-Central States accounted for more than 60 percent of this production for the year. Table 2-2 lists the number of wood preserving plants by State.

Treatment by waterborne preservatives amounted to 77.8 percent of the total production, followed by creosote (15.9 percent), oilborne preservatives (5.7 percent) and fire retardants (0.6 percent). In terms of volume treated, the most commonly treated product was lumber, which accounted for 43.4 percent of the total volume treated, followed by timber (12.8 percent), crossties (12.8 percent), and poles (11.9 percent). A summary of 1995 production by type of product and preservative is presented in Table 2-3. Consumption of preservatives in 1995 are summarized in Table 2-4, and production by wood species is summarized in Table 2-5.

2.2 PROCESS DESCRIPTION¹⁻⁹

2.2.1 Preservatives

There are two general classes of wood preservatives: oils, such as creosote and petroleum solutions of pentachlorophenol; and waterborne salts that are applied as water solutions. The effectiveness of the preservatives varies greatly and can depend not only upon their composition, but also upon the quantity injected into the wood, the depth of penetration, and the conditions to which the treated material is exposed in service. The following paragraphs describe the general characteristics of the major preservative types. Table 2-6 provides a list of the components of some of the most commonly used preservative formulations.

Coal tar creosote. Coal tar creosote is described by the American Wood-Preservers' Association as, "a distillate of coal tar produced by high temperature carbonization of bituminous coal; it consists principally of liquid and solid aromatic hydrocarbons and contains appreciable quantities of tar acids and tar bases." It is heavier than water, and has a continuous boiling range from about 200°C (392°F) to 540°C (1000°F).

There are approximately 200 compounds in coal tar creosote, most of which are polycyclic aromatic hydrocarbons (PAH's). The relative concentrations of these components can vary because of the character of the tar, variations in the distillation process, and other factors. The components also serve to complement each other in effecting the wood preservation because the lighter molecules are usually more toxic to decay

organisms, while the heavier molecules help prevent moisture changes and splitting of the wood, and help "retain" the lighter, more toxic compounds.

Creosote solutions. Coal tar creosote can be mixed with petroleum oil to lower the cost of the preservative and still exhibit a satisfactory performance. Creosote-petroleum solutions help reduce splitting and weathering of the treated wood, and frequently out-perform straight creosote for wood preservation. Creosote-coal tar distillate solutions also have been used for wood treating, but are no longer in use in the United States.

Pentachlorophenol solutions. These solutions consist primarily of chlorinated phenols and heavy petroleum oils. Methylene chloride and liquid petroleum gas also have been used as solvents in pentachlorophenol solutions, but no longer are in use in the United States. The primary use of pentachlorophenol solutions is in the treatment of utility poles.

Waterborne preservatives. Standard wood preservatives used in water solution include chromated copper arsenate (CCA), Types A, B, and C, and ammoniacal copper zinc arsenate (ACZA). Waterborne preservatives generally leave the wood surface clean, paintable, and free from objectionable odor. They typically are used at low treating temperatures (38° to 66°C [100° to 150° F]) because they are unstable at higher temperatures.

The ACZA and CCA formulations are included in specifications for such items as building foundations, building poles, utility poles, marine piles, and piles for land and fresh water use, as well as for above-ground uses.

2.2.2 Conditioning

With most wood treating methods, significant amounts of free water in the wood cell cavities may slow or prevent the entrance of the preservative chemical. Therefore, wood moisture content must be reduced prior to treatment. Moisture reduction can be accomplished by using artificial conditioning treatments or by air-seasoning (i.e., storing the untreated wood outdoors in piles). Unseasoned wood that is exposed to the open air generally dries slowly until it comes into approximate equilibrium with the relative humidity of the air. However, some wood species will rot before the air drying is complete.

Because certain wood species will rot before air drying can be completed in some climates, wood is artificially conditioned by one of three primary methods: (1) steaming-and-vacuum, (2) boiling-under-vacuum (commonly referred to as the Boulton process), and (3) kiln drying. Vapor drying also has been used, but currently is used rarely, if ever. These conditioning treatments remove a substantial amount of moisture from the wood and also heat the wood to a more favorable treating temperature. Steaming and Boultonizing have the added effect of disinfecting the wood. In segregated systems, conditioning is performed in separate "clean" cylinders that do not contain preservatives.

The steaming and vacuum method of conditioning is used primarily for treating southern pine poles. Steaming and vacuum may be performed in a dedicated cylinder or in the same cylinder used for treating the wood. In this process, the wood charge is heated with live steam. Then, a vacuum is drawn.

The Boulton process is used primarily for Douglas fir and hardwoods. The Boulton process usually is performed in the same cylinder used to treat the wood. In this process, the cylinder is charged with wood, and heated preservative is used to heat the wood charge for 1 to 24 hours. At that point, a vacuum is drawn. Finally, the preservative is returned to the work tank. This step is referred to as "blow back" from the

practice of using compressed air to blow the preservative back into the work tank. However, many treatment systems use pumps to withdraw preservative from the treatment cylinder and return it to the work tank. Although such systems do not actually blow back the preservative, the term still is used to refer to this step of the process.

2.2.3 Treating

Most wood-preserving methods may be classified as either pressure processes, in which the wood is placed in a treating cylinder or retort and impregnated with preservative under considerable force, and nonpressure processes, which do not involve the use of induced pressure. Nonpressure processes can be classified as thermal processes, in which heat is applied, and nonthermal processes, such as brushing, spraying, dipping, and soaking. Nonpressure processes generally are used only with oilborne preservatives. Because the majority of wood treated annually is impregnated by pressure methods in closed cylinders, only pressure processes are discussed in the following sections.

Pressure processes operate on the same general principle, though they may differ in the specifics of the process. The treatment is carried out in steel cylinders or retorts. Most units conform to size limits of 2 to 3 m (6 to 9 ft) in diameter and up to 46 m (150 ft) or more in length, and are built to withstand working pressures up to 1,720 kilopascals (kPa) (250 pounds per square inch [psi]). The wood is loaded on special tram cars and moved into the retort, which is then closed and filled with preservative. Pressure is applied to force the preservative into the wood until the desired amount has been absorbed. Three processes, the full-cell, modified full-cell, and empty-cell, are in common use. These processes are distinguished by the sequence in which vacuum and pressure are applied to the retort. The terms “empty” and “full” refer to the level of preservative retained in the wood cells. The full cell process achieves a high level of retention of preservative in the wood cells, but less penetration than the empty cell process, and the empty cell process achieves relatively deep penetration with less preservative retention than does the full cell process.

Full-cell process. The full-cell (Bethel) process is used when maximum preservative retention levels are desired, such as when treating timbers with creosote for protection against marine borers. Figure 2-1 presents a flow diagram for the full-cell pressure treating process. In addition to creosote, the full-cell process also is used primarily with waterborne preservatives. The full-cell process steps are listed below:

1. The charge of wood is sealed in the treating cylinder, and an initial vacuum is applied for approximately half an hour to remove as much air as possible from the wood and from the cylinder;
2. The preservative, either heated or at ambient temperature depending on the system, enters the cylinder without breaking the vacuum;
3. After the cylinder is filled, the cylinder is pressurized until no more preservative will enter the wood or until the desired preservative retention is obtained;
4. At the end of the pressure period, the pressure is released, and the preservative is removed from the cylinder; and
5. A final vacuum may be applied to remove the excess preservative that would otherwise drip from the wood.

If the wood is steam-conditioned, the preservative is introduced after the vacuum period following steaming. The final steps in the process are the unloading of the retort and storage of the treated wood.

Modified full-cell process. The modified full-cell process generally is used for the application of waterborne preservatives. This method is similar to the full-cell process except for the initial vacuum levels. The modified full-cell process uses lower initial vacuums, which are determined by the wood species being treated and the preservative retention levels desired. The flow diagram shown in Figure 2-1 also characterizes the modified full-cell pressure treating process.

Empty-cell process. The empty-cell process obtains deep preservative penetration with a relatively low net preservative retention level. If oil preservatives are used, the empty-cell process most likely will be used, provided it will yield the desired retention level. The Rueping process and the Lowry process are the two most commonly used empty-cell processes. Both use compressed air to drive out a portion of the preservative absorbed during the pressure period. Figure 2-2 presents a flow diagram for the empty-cell pressure treating process.

In the Rueping process, compressed air is forced into the treating cylinder containing the charge of wood to fill the wood cells with air prior to preservative injection. Pressurization times vary with wood species. For some species only a few minutes of pressurization are required, while more resistant species may require pressure periods of from 30 minutes to 1 hour. Air pressures used typically range from 172 to 690 kPa (25 to 100 psi) depending on the net preservative retention desired and the resistance of the wood.

After the initial pressurization period, preservative is pumped into the cylinder. As the preservative enters the treating cylinder, the air escapes into an equalizing or Rueping tank at a rate which maintains the pressure within the cylinder. When the treating cylinder is filled with preservative, the pressure is raised above that of the initial air and maintained until the wood will not take any more preservative or until enough has been absorbed to leave the desired preservative retention level after the final vacuum.

After the pressure period, the preservative is removed from the cylinder, typically by pumping, and surplus preservative is removed from the wood with a final vacuum. This final vacuum may recover from 20 to 60 percent of the gross amount of preservative injected. The retort then is unloaded, and the treated wood stored.

The Lowry process is an empty-cell process without the initial air pressure. Preservative is pumped into the treating cylinder without either an initial air pressurization or vacuum, trapping the air that is already in the wood. After the cylinder is filled with the preservative, pressure is applied and the remainder of the process is identical to the Rueping process.

The advantage of the Lowry process is that full-cell equipment can be used without the accessories required by the Rueping process, such as an air compressor, an extra tank for the preservative, or a pump to force the preservative into the cylinder against the air pressure. However, both processes are used widely and successfully.

2.3 EMISSIONS^{1-2,5-6,9}

For waterborne preservatives, emissions from wood preserving processes generally are not significant. For oilborne preservatives, the primary sources of emissions from wood preservation processes are: (1) the treated charge immediately after removal from the treating cylinder, (2) the vacuum system (conditioning cycle and final vacuum cycle), and (3) displaced air from working tank blow backs.

The elevated temperature of the treated charge when it is pulled from the cylinder causes some of the lower boiling point organic compounds to volatilize as aerosols, forming a white emission plume that

typically dissipates within a few minutes. Volatile organic compound emissions include those organic compounds present in the wood that are released when heated during conditioning and treatment, and the PAH's that are evaporated from the creosote solution and removed from the retort through the vacuum system during the Boulton (boiling-under-vacuum) process and during the final vacuum applied during the Rueping process. Creosote emissions can be estimated as the sum of the emissions of the PAH's.

The emission point for the steaming and vacuum method of conditioning is the vacuum pump system vent. Vacuum systems include condensers, which are considered part of the process equipment and not separate emission control devices. The emission points for the Boulton process are the vacuum pump vent during the vacuum stage of the conditioning process and the work tank vent during the blow back or preservative withdrawal stage of the conditioning process.

Working tank blow backs also occur at the end of a preservative treatment cycle when the treating solution is returned to the work tank. The air displaced by the returning solution is vented via a control device to the atmosphere. In some systems, the displaced air in the work tank is vented back into the treatment cylinder to fill the head space created as the preservative is withdrawn from the cylinder. In such systems, there are no emissions associated with blow backs. A problem may arise when the quantity of preservative being blown back is not monitored closely and air begins to blow up through the work tank. Volatile compounds are picked up by the air as it bubbles up through the treating solution and are carried out through the tank vent.

In addition to the three primary process emission sources, emissions are generated from wastewater treatment and organic liquid storage tanks. Oilborne wood treatment plants frequently have on-site wastewater treatment facilities designed to separate organic materials from the wastewater generated during the treating process. This wastewater treatment is a potential source of VOC and HAP emissions. Emission factors for this source are not presented in this section, as they are more appropriate for AP-42 Chapter 4, Evaporation Loss Sources, Section 4.3, Waste Water Collection, Treatment and Storage.

Liquid storage tanks for the various preservatives are also sources of VOC and HAP. Emissions from these storage tanks are covered in AP-42 Chapter 7, Liquid Storage Tanks.

2.4 CONTROL TECHNOLOGY^{1-2,9-12}

There are few options for controlling fugitive emission losses from treated charges. Constructing a ventilation hood to collect VOC's emanating from the freshly treated charge is economically infeasible due to the size of the hood needed for covering the cylinder end and drip pad. The effectiveness of controlling emissions by using water to cool freshly treated wood by spraying or quenching is questionable. A primary drawback to the water quench systems is that the contaminant is merely transferred to water, resulting in the need for an effluent treatment system. In addition, water quench systems generate significant amounts of wastewater which include listed hazardous substances, and, thus, is not desirable.

A 1993 survey of 97 wood preserving facilities found that at least eight facilities used wet scrubbers for controlling emissions from creosote wood preserving vacuum systems and/or working and storage tank vents; use of both venturi scrubbers and packed-bed scrubbers was reported. One facility also reported using a packed-bed scrubber to control VOC emissions from a PCP wood preserving process. At least two creosote facilities used condensers and one facility used an incinerator to control VOC emissions from creosote wood preserving. The results of one emissions test on the incinerator-controlled facility indicated a VOC control efficiency of more than 99 percent for the Boulton process and first blowback. None of the wood preserving facilities currently in operation use incineration for emission control. A few facilities control emissions from

creosote wood preserving processes by means of a knock-out tank followed by a venturi scrubber. The results of an emission test on such a system indicated a VOC control efficiency of 75 percent.

Odorous emissions from some steam jet vacuum systems suggest that a single-pass water-cooled condenser may not condense all of the organics in the exhaust. One option for correcting this problem is to install a larger condenser capable of further reducing the organic content in the vapor. A properly sized condenser with adequate cooling water will condense virtually all of the organics in the exhaust stream. Another option is to modify the vacuum system to include two steam jet ejectors in series with a barometric (direct contact) intercondenser between them. In this system, the barometric intercondensers condense the oily vapors in the steam and remove them with the intercondensed water. A third option is to replace the steam jet ejectors with a vacuum pump and duct the exhaust vapors to an activated carbon adsorption system or to an afterburner. Both are efficient means for removing organic compounds from the exhaust gas.

Working tank blow back vapors can be controlled by bubbling the vapors through water or through a water spray before venting to the atmosphere. However, the effectiveness of these systems will deteriorate if the water is allowed to reach saturation and is not changed periodically. Another option for controlling these vapors is to incinerate them with the vacuum system exhaust. However, incinerators are not in use currently at any domestic wood preserving facilities.

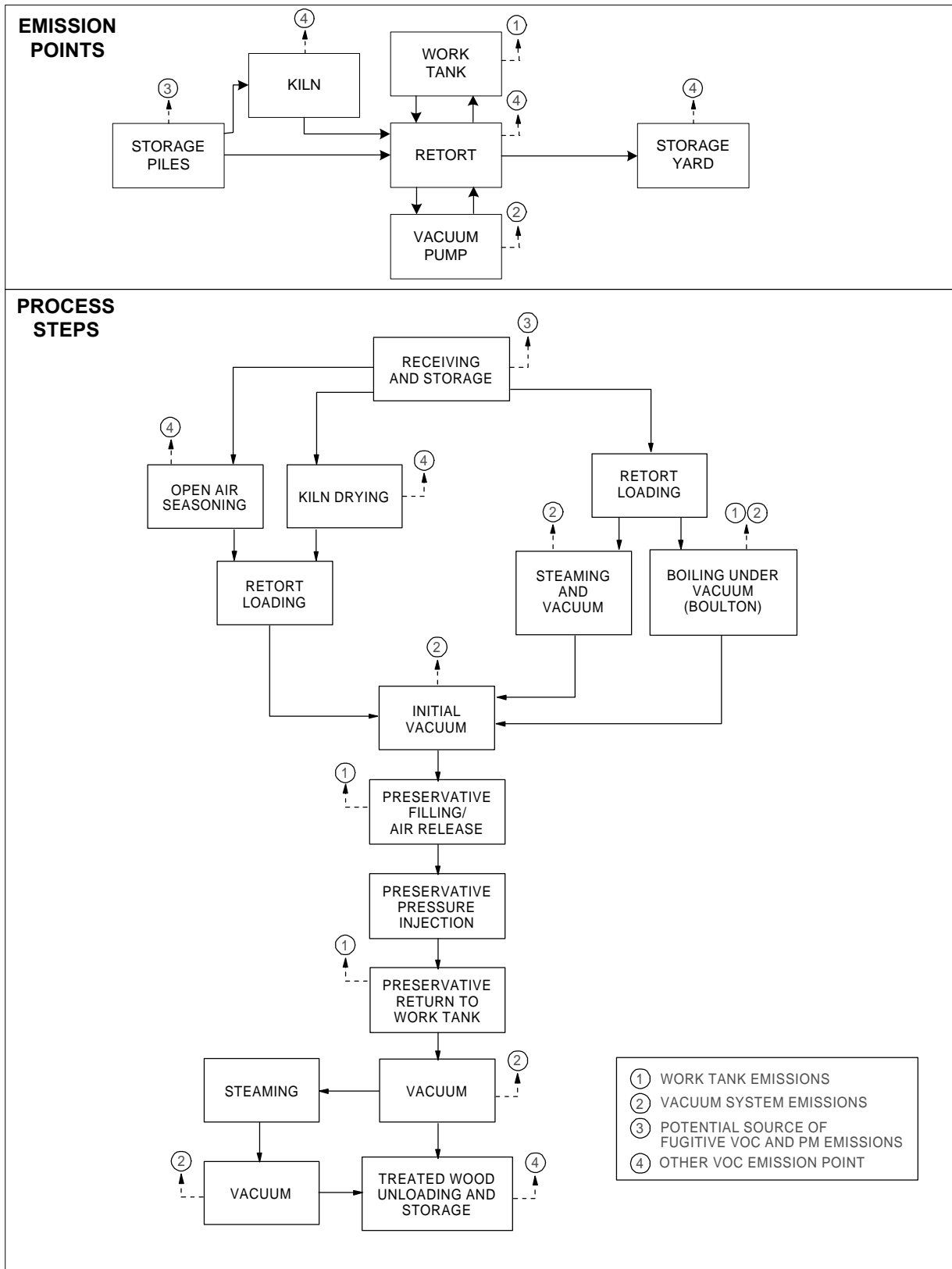


Figure 2-1. Flow diagram of the full-cell and modified full-cell pressure treating processes.

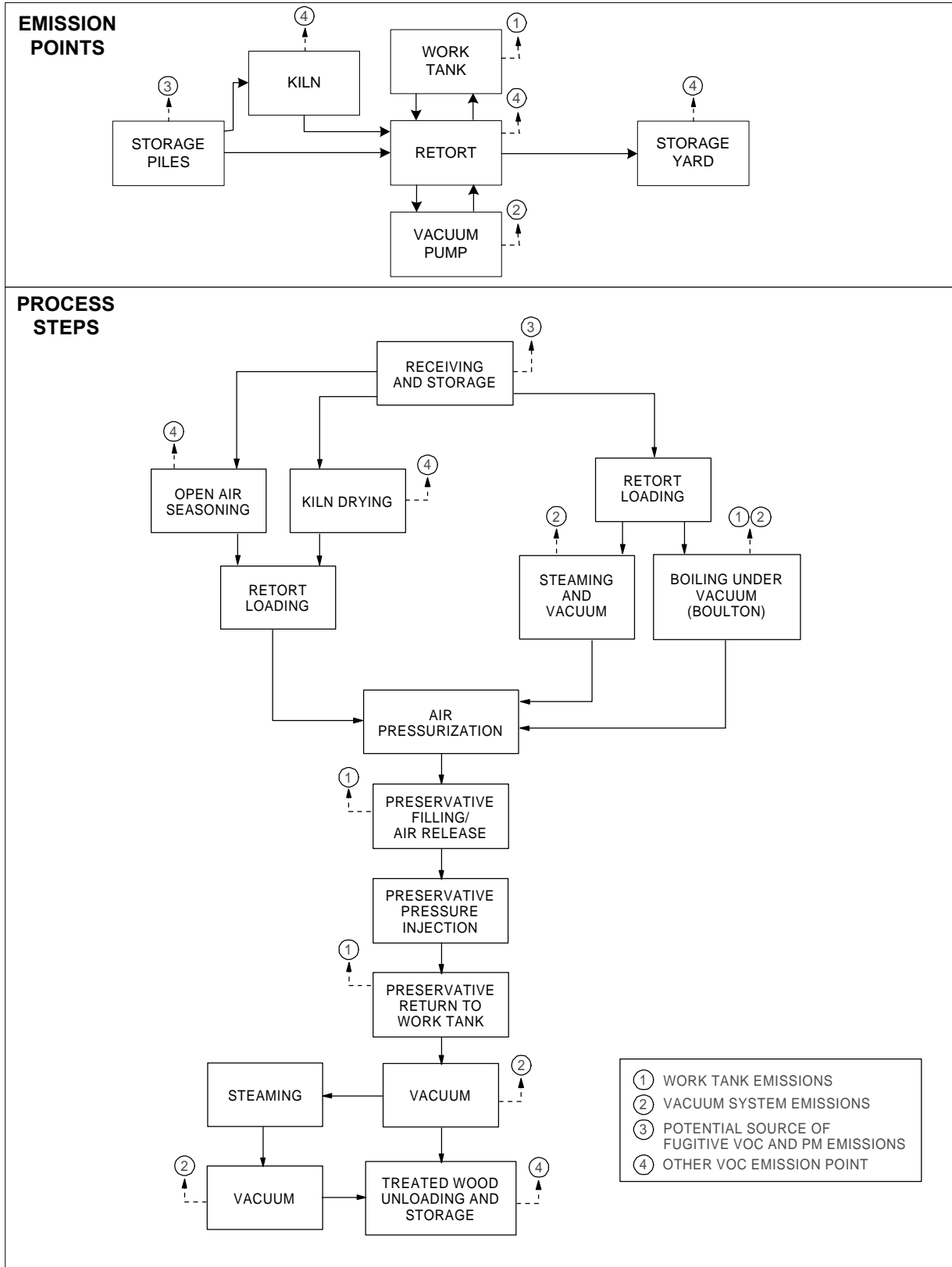


Figure 2-2. Flow diagram for the empty-cell pressure treating process.

TABLE 2-1. SUMMARY OF SOURCE CLASSIFICATION
CODES FOR WOOD PRESERVING

SCC	Description
3-07-005-01	Wood pressure treating, creosote ** (use process-specific SCCs)
3-07-005-05	Untreated wood storage
3-07-005-10	Full-cell process, creosote
3-07-005-11	Full-cell process, pentachlorophenol
3-07-005-12	Full-cell process, other oilborne preservative
3-07-005-20	Full-cell process with artificial conditioning, creosote
3-07-005-21	Full-cell process with artificial conditioning, pentachlorophenol
3-07-005-22	Full-cell process with artificial conditioning, other oilborne preservative
3-07-005-13	Modified full-cell process, chromated copper arsenate
3-07-005-14	Modified full-cell process, other waterborne preservative
3-07-005-23	Modified full-cell process with artificial conditioning, chromated copper arsenate
3-07-005-24	Modified full-cell process with artificial conditioning, other waterborne preservative
3-07-005-30	Empty-cell process, creosote
3-07-005-31	Empty-cell process, pentachlorophenol
3-07-005-32	Empty-cell process, other oilborne preservative
3-07-005-33	Empty-cell process, chromated copper arsenate
3-07-005-34	Empty-cell process, other waterborne preservative
3-07-005-40	Empty-cell process with artificial conditioning, creosote
3-07-005-41	Empty-cell process with artificial conditioning, pentachlorophenol
3-07-005-42	Empty-cell process with artificial conditioning, other oilborne preservative
3-07-005-43	Empty-cell process with artificial conditioning, chromated copper arsenate
3-07-005-44	Empty-cell process with artificial conditioning, other waterborne preservative
3-07-005-50	Empty-cell process with steam heating, creosote
3-07-005-51	Empty-cell process with steam heating, pentachlorophenol
3-07-005-52	Empty-cell process with steam heating, other oilborne preservative
3-07-005-53	Empty-cell process with steam heating, chromated copper arsenate
3-07-005-54	Empty-cell process with steam heating, other waterborne preservative
3-07-005-60	Empty-cell process with artificial conditioning and steam heating, creosote
3-07-005-61	Empty-cell process with artificial conditioning and steam heating, pentachlorophenol
3-07-005-62	Empty-cell process with artificial conditioning and steam heating, other oilborne preservative
3-07-005-63	Empty-cell process with artificial conditioning and steam heating, chromated copper arsenate

TABLE 2-1. continued

SCC	Description
3-07-005-64	Empty-cell process with artificial conditioning and steam heating, other waterborne preservative
3-07-005-90	Treated wood storage, creosote
3-07-005-91	Treated wood storage, pentachlorophenol
3-07-005-92	Treated wood storage, other oilborne preservative
3-07-005-93	Treated wood storage, chromated copper arsenate
3-07-005-94	Treated wood storage, other waterborne preservative
3-07-005-97	Wood pressure treating, other not classified
3-07-005-98	Wood pressure treating, other not classified
3-07-005-99	Wood pressure treating, other not classified

TABLE 2-2. WOOD PRESERVING PLANTS BY STATE^a

State	No. of plants
Alabama	39
Alaska	0
Arizona	2
Arkansas	17
California	11
Colorado	5
Connecticut	1
Delaware	0
Florida	25
Georgia	40
Hawaii	5
Idaho	5
Illinois	9
Indiana	7
Iowa	2
Kansas	0
Kentucky	8
Louisiana	15
Maine	1
Maryland	6
Massachusetts	3
Michigan	11
Minnesota	9
Mississippi	21
Missouri	9
Montana	2

State	No. of plants
Nebraska	2
Nevada	1
New Hampshire	1
New Jersey	2
New Mexico	1
New York	6
North Carolina	28
North Dakota	1
Ohio	11
Oklahoma	3
Oregon	10
Pennsylvania	19
Rhode Island	1
South Carolina	17
South Dakota	3
Tennessee	7
Texas	28
Utah	2
Vermont	0
Virginia	20
Washington	13
West Virginia	9
Wisconsin	11
Wyoming	2
Total ^a	451

^aReference 3.

TABLE 2-3. PRODUCTION OF TREATED WOOD IN THE UNITED STATES, 1995^a

Product	Volume of wood treated, 1,000 ft ³				
	Creosote solution ^b	Oilborne preservatives ^c	Waterborne preservatives ^d	Fire retardants	Total
Crossties	69,947	0	4,177	0	74,124
Switch and bridge ties	6,125	360	2,647	0	9,132
Poles	8,941	30,617	29,215	0	68,773
Piling	1,415	0	7,820	0	9,235
Fence posts	244	339	18,204	0	18,787
Lumber	1,810	320	247,436	1,714	251,280
Timber	1,754	77	72,031	0	73,862
Plywood	e	3	16,528	2,049	18,580
Other ^f	1,515	1,048	52,538	0	55,101
Total	91,751	32,764	450,596	3,763	578,874

^aReference 3.

^bCreosote, creosote-coal tar, and creosote-petroleum.

^cCopper naphthenate, pentachlorophenol, and others.

^dChromated copper arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), acid copper chromate (ACC), ammoniacal copper quat (ACQ), and others.

^eIncluded in "other" category.

^fIncludes crossarms, landscape timbers, highway posts and guardrails, mine ties and timbers, crossing planks, and other miscellaneous products.

TABLE 2-4. SUMMARY OF PRESERVATIVES CONSUMED IN 1995^a

Preservative	Consumption
CCA (Chromated Copper Arsenate)	138,470,000 pounds
Other waterborne preservatives (includes ACZA, ACQ, ACA, etc.)	8,693,000 pounds
Oilborne preservatives	
Total	39,734,000 gallons
(concentrate)	8,588,000 gallons
(solvent)	31,146,000 gallons
Creosote solutions	92,000,000 gallons
Fire retardants	7,832,000 pounds

^aReference 3.

TABLE 2-5. 1995 PRODUCTION
BY WOOD SPECIES^a

Wood species	Volume as percentage of total
Douglas Fir	3.6
Hemlock	3.8
Lodgepole pine	0.9
Mixed hardwoods	4.7
Mixed softwoods	0.8
Norway pine	0.1
Oak	9.3
Ponderosa pine	2.3
Southern yellow pine	69.0
Other	5.3
TOTAL	100

^aReference 3.

TABLE 2-6. COMPOSITIONS OF COMMON WOOD PRESERVATIVES^a

Preservative	Chemical constituent	Composition, percent
Oilborne preservatives		
Creosote ^b	phenanthrene	21
	fluorene	10
	fluoranthene	10
	acenaphthalene	9
	pyrene	8.5
	dibenzofuran ^c	5
	methylanthracenes	4
	naphthalene ^c	3
	methylfluorenes	3
	methylphenanthrenes	3
	chrysene	3
	dimethylnaphthalenes	2
	anthracene	2
	carbazole	2
	benzofluorenes	2
	2-methylnaphthalene	1.2
1-methylnaphthalene	0.9	
biphenyl ^c	0.8	
Pentachlorophenol (PCP)	chlorinated phenols ^c	≥5
	hydrocarbon solvents	≤95
Copper naphthenate	copper naphthenate	6 to 8
	hydrocarbon solvents	92 to 94
Solubilized copper-8-quinolinolate	copper-8-quinolinolate	≥10
	nickel-2-ethylhexoate ^c	≥10
	hydrocarbon solvents	≤80
Alkyl ammonium compound (AAC)	didecyltrimethylammonium chloride	≥90
	dialkyltrimethylammonium chlorides	≤10
Waterborne preservatives		
Acid copper chromate (ACC)	copper, as CuO	28.0 to 31.8
	hexavalent chromium, as CrO ₃ ^c	63.3 to 68.2
Ammoniacal copper arsenate (ACA)	copper, as CuO	47.7 to 49.8
	arsenic, as As ₂ O ₅ ^c	47.6 to 50.2
	dissolved in a solution of ammonia (NH ₃) in water	
Ammoniacal copper zinc arsenate (ACZA)	copper, as CuO	45.0 to 55.0
	zinc, as ZnO	22.5 to 27.5
	arsenic, as As ₂ O ₅ ^c	22.5 to 27.5
	dissolved in a solution of ammonia (NH ₃) in water	
Chromated copper arsenate, (CCA), Type A	hexavalent chromium, as CrO ₃ ^c	59.4 to 69.3
	copper, as CuO	16.0 to 20.9
	arsenic, as As ₂ O ₅ ^c	14.7 to 19.7
Chromated copper arsenate, (CCA), Type B	hexavalent chromium, as CrO ₃ ^c	33.0 to 38.0
	copper, as CuO	18.0 to 22.0
	arsenic, as As ₂ O ₅ ^c	42.0 to 48.0
Chromated copper arsenate, (CCA), Type C	hexavalent chromium, as CrO ₃ ^c	44.5 to 50.5
	copper, as CuO	17.0 to 21.0
	arsenic, as As ₂ O ₅ ^c	30.0 to 38.0
Chromated zinc chloride (CZC)	hexavalent chromium, as CrO ₃ ^c	19 to 20
	zinc, as ZnO	76 to 80

^aReferences 1,4 and 7.

^bConstituent concentrations vary depending on the source of the creosote.

^cHazardous air pollutant.

REFERENCES FOR SECTION 2

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10. *Draft Industry Profile*, technical memorandum from B. Gatano, Research Triangle Institute, to Eugene Crumpler, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 2, 1993.
11. *Wood Treatment Plant Emission Test Report, Kerr-McGee Chemical Corporation, Avoca, Pennsylvania, EMB Report 94-WDT-01*, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1994.
12. *Gaseous Organic Compound Emission Study, Naphthalene Knock-Out Tank and Water Scrubber, Birmingham Wood, Inc., Warrior, Alabama, Allied Signal, Inc., April 12 & 13, 1994*, T.L., Inc., Tuscaloosa, AL, May 1994.

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The Emission Standards Division provided test reports and other information on the industry, processes, and emissions. The Factor Information and Retrieval (FIRE), Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these data bases.

A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the wood preserving industry. However, no test reports were located using the TSAR data base. The EPA library was searched for additional test reports. Using information obtained on plant locations, individual facilities and State and Regional offices were contacted about the availability of test reports. In addition, the American Wood Preservers Institute, the Railway Tie Association, and specific facilities within the industry provided review and comments of draft versions of this report.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:
 - a. Source testing must be from a referenced study that does not reiterate information from previous studies.
 - b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.
2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM¹

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and
5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A—Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B—Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C—Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D—Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM¹

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed only from A- and B-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B-, and/or C-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A-, B-, and/or C-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Section 4.

REFERENCE FOR SECTION 3

1. *Procedures for Preparing Emission Factor Documents*, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1997.

4. AP-42 SECTION DEVELOPMENT

4.1 DEVELOPMENT OF SECTION NARRATIVE

The draft AP-42 section is a new section addressing wood preserving processes. The new section is based on information gathered from the references cited, and includes a description of the industry, process diagrams, and emission factors for specific process emission points.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

Eighteen references were documented and reviewed in the process of developing emission factors for the section on wood preserving. Table 4-1 presents a list of these references. Twelve of the eighteen references could not be used to develop emission factors. Table 4-2 lists the reasons for rejecting those references. The following subsection describes the six references (References 10, 11, 13, 15, 16, and 17) that were used for emission factor development. In addition, a fourth reference (Reference 14) is described because it provides representative control efficiency data.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 10. The objective of this project was to measure and/or estimate the emission rates of toxic compounds that are emitted from the Koppers Industries, Incorporated, wood treatment facility in Oroville, California. The facility uses the empty-cell process for both creosote and chromated copper arsenate wood preserving. A literature review was conducted to establish the best methods to measure the stack emissions and fugitive emissions. Emission factors based on material balance calculations were used to estimate the emission rates from those sources that could not be directly sampled. A program of ambient air quality monitoring and meteorological monitoring was conducted at the site in October 1988 to measure the evaporative emissions from the treated wood storage area. A stack sampling and wastewater sampling program was conducted at the site in February 1989.

Emissions were sampled from the creosote vacuum system vents during the conditioning cycle and the additional vacuum cycle (following steaming); the creosote working tank vents during blowback and during the steam cycle; and the CCA vacuum system vents during the vacuum cycle. Two EPA Method 5 test runs were conducted on the CCA cylinder vacuum exhaust to measure particulate and vapor phase metals. Three volatile organic sampling train (VOST) and semivolatile organic sampling train (semi-VOST) test runs were conducted on the No. 4 creosote cylinder vacuum system exhaust during the conditioning cycle and during the final vacuum cycle. Two VOST and semi-VOST test runs were conducted on the No. 4 creosote working tank vent during blowback and during the steam cycle.

The report does not specify the volume of wood charged during the testing. In addition, emission rates are reported only in units of kilograms per year, and other test data are not provided in the report. However, the report provides typical annual production rates and the corresponding number of loads (cycles). By assuming a typical density of 640 kg/m³ (40 lb/ft³), emission factors were developed for various process steps. Emission factors were developed only for those pollutants for which concentrations in the exhaust stream were above the detection limit. The report provides no information on emission controls; it is assumed that the data represent uncontrolled emissions.

Emission factors for several speciated organic compounds were calculated for creosote working tank vent blowback and steam cycle emissions and creosote vacuum system conditioning cycle and final vacuum emissions. Emission factors for total chromium and copper were calculated for CCA vacuum system

emissions. Because of the lack of details on the process and the tests conducted, the emission data were rated D.

4.2.1.2 Reference 11. This report documents measurements of emissions from a creosote wood treating facility. The test, which was conducted in September 1993, was sponsored by EPA for the purposes of establishing baseline HAP emissions and the maximum achievable control technology for creosote wood treating industry.

The facility uses the Boulton process to condition wood prior to treating the wood by the empty-cell (Rueping) process. Emissions were sampled from two wood treating cylinders, each of which measured 2.1 m in diameter by 46 m in length (7 ft in diameter by 150 ft in length). Emissions from the cylinders are controlled with a natural gas-fired thermal incinerator. Emissions from the cylinders were sampled for VOC at both the inlet and outlet to the incinerator using Method 25A. Two runs were conducted. The first run was conducted on one of the cylinders and encompassed a 14-hr Boulton conditioning cycle and a 4-hr final vacuum cycle. The second run was conducted on the other cylinder and included a 12-hr Boulton cycle. However, the second run was terminated prematurely due to a cylinder gasket failure during the pressurization cycle. Furthermore, because one of the two Method 25A analyzers was damaged during shipment to the site, it was not possible to measure both inlet and outlet concentrations during complete test runs. Instead, incinerator inlet emissions were quantified during the first 7.75 hr of the Boulton cycle of Run 1, at which time the analyzer was moved to the incinerator outlet for the remainder of the treating cycle. During the second run, the analyzer was located at the incinerator outlet during the entire cycle, and a second analyzer was obtained and positioned to sample incinerator inlet emissions at approximately 4 hr into Run 2. Run 2 was terminated when the cylinder gasket failed.

Inlet emissions were quantified for the Boulton cycle; the first blowback, which occurs when the Boulton cycle vacuum is broken and the creosote is withdrawn from the cylinder; and the subsequent pressurization of the cylinder. With the exception of brief periods, approximately 30 seconds in length, the VOC emission concentrations at the incinerator outlet were below the detection limit of 2 parts per million. In addition to the emissions measurements, the creosote was sampled and analyzed for 66 organic compounds, 16 of which were found in concentrations above the detection limit of 2.0 micrograms per milliliter ($\mu\text{g/ml}$). Table 4-3 lists these compounds and their concentrations.

Emission factors were developed for uncontrolled VOC emissions from the Boulton process and the first blowback of the empty cell (Rueping) process. In addition, the incinerator control efficiency was determined to be more than 99 percent for the Boulton process and the first blowback. Emission rates also were reported for the pressurization step following the first blowback. However, the emissions are the result of the air flow generated by the induced draft fan on the control system; the pressurization step is a closed process and, as such, does not generate emissions. Therefore, an emission factor was not developed from the pressurization emission data. The emission data for the conditioning step (Boulton process) are rated C because sampling was not performed over the entire cycle. The emission data for the first blowback are rated B. It should be noted that this incinerator is no longer in use.

4.2.1.3 Reference 13. This report documents measurements of emissions from a creosote wood treating facility. The test, which was conducted in May 1990, was sponsored by the facility for the purpose of determining emissions of creosote compounds from the process.

The facility uses the Boulton process to condition wood prior to treating the wood by the empty-cell (Rueping) process. Emissions were sampled from two wood treating cylinders, each of which measured 2.4 m in diameter by 43 m in length (8 ft in diameter by 140 ft in length). Emissions from the cylinders are

controlled with a condenser, and samples were collected at both the inlet and outlet of the condenser. Emissions from the cylinders were sampled using a modified Method 5 with an XAD absorbent canister. A composite sample was collected during a 1-hr period of the 6- to 7-hr Boulton cycles on both cylinders, and a second 1-hr sample was collected from one of the cylinders later in the Boulton process. Following the conditioning and the initial pressurization steps, six samples were collected over the 22-minute air pressure release cycle for one cylinder, and samples were collected over a one-hr period of the final 2-hr vacuum for one of the cylinders. The samples were analyzed for 18 polycyclic aromatic hydrocarbons (PAHs) according to Method 610.

Emission factors were developed for uncontrolled emissions from the conditioning cycle, air pressure release, and final vacuum steps of the process. The results of the condenser outlet emissions samples were inconclusive due to high fluctuations in flow measurements and sample concentrations, and emission factors were not developed for controlled emissions. The emission data are rated C because sampling was not performed over the entire cycle for each steps in the wood treating process.

4.2.1.4 Reference 14. This report documents measurements of emissions from a creosote wood treating facility. The test, which was conducted in April 1994, was sponsored by the facility for the purpose of determining the effectiveness of a knock-out tank and wet scrubber in controlling emissions from the wood treating process.

The facility uses the Boulton process to condition wood prior to treating the wood by the empty-cell (Rueping) process. Emissions were sampled from two wood treating cylinders. One of the cylinders measured 2.1 m in diameter by 18.6 m in length (7 ft in diameter by 61 ft in length), and the other cylinder measured 1.8 m in diameter by 15.5 m in length (6 ft in diameter by 51 ft in length). Emissions from the cylinder vacuum systems were ducted together, and the combined gas stream was ducted to a naphthalene knock-out tank, followed by a venturi scrubber. Creosote storage tank emissions were vented directly to the same venturi scrubber. Emissions were sampled at the inlet of the knock-out tank and the scrubber outlet. Volatile organic compound emissions were sampled using Method 25A.

Emission factors could not be developed from the data because process rates were not reported, and the emissions streams sampled included emissions from both cylinders, which were out of phase with one another (e.g., while one cylinder was being pressurized, preservative was being withdrawn from the other). However, the overall control efficiency determined from the data should be representative of the effectiveness of the emission controls used. This overall VOC control efficiency was determined to be 75 percent.

4.2.1.5 References 15, 16, 17, and 20. Reference 15 is an emission test report, and References 16, 17, and 20 provide supplemental data for Reference 15. The following paragraphs describe these references in more detail.

Reference 15 presents the results of an emission test to quantify fugitive emissions from the storage of creosote-treated wood. The test was performed for the California Hot Spots Program (AB 2588). A temporary total enclosure was constructed, and treated poles were placed in the enclosure. The enclosure was sealed, and air was drawn through the enclosure at the rate of 3,000 actual cubic feet per minute simulate a 2 mile per hour wind. A series of emission tests were performed on the exhaust line from the enclosure. In each test, emissions from six treated utility poles were sampled. The poles were approximately 10 inches in diameter and 45 feet long. Total surface area for the poles was reported as 699 ft². Sampling was performed on a set of freshly-treated poles, 1-day old poles (time since treatment), 4-day old poles, 7-day old poles, 12-day old poles, and 30-day old poles.

Emissions samples were analyzed for several organic pollutants. The samples were tested for 17 polyaromatic hydrocarbons (PAH's) using CARB Method 429; CARB Method 430 was used to sample for formaldehyde emissions; emissions of benzene and toluene were measured using CARB Method 410/422; and the samples were analyzed for phenols and creosols by EPA Method TO-8. Three runs each were performed with the fresh poles, 1-day old poles, and 4-day old poles; only one run was performed on the 7-day, 12-day, and 30-day old poles. Background samples also were analyzed. The Method 429 tests quantified emissions of eight PAH's: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthracene, anthracene, fluoranthene, and pyrene. Emissions of the other PAH's were not detected. The Method 430 tests for formaldehyde yielded inconsistent results; for many of the test runs formaldehyde concentrations were less than the background concentrations. It was suspected that formaldehyde emissions from a nearby wood panelboard plant were at least partly responsible for the erratic measurements. As a result, the formaldehyde results were not considered to be valid. The Method 410/422 results also were not useful; benzene concentrations were below detection limit for all runs, and the toluene concentrations were near or below the background concentrations on most runs. Finally, the TO-8 detected none of the target phenols and cresols.

Reference 16 is a report that presents a method for estimating fugitive emissions of naphthalene from the storage of creosote-treated cross-ties and poles. The method is based on simple linear regressions of the natural logs of the emission test data presented in Reference 15. Three separate equations are developed, which, according to the report, correspond to three specific phases of emissions following removal of creosote-treated wood from the retort. The first phase, which is referred to as the temperature-driven emissions, encompasses the first 6 hours following removal from the retort. The second phase is characterized by thin film emissions, which occur during the next 18 hours. During the final phase, pore-space emissions occur. The final phase continues indefinitely. However, during this phase, the emission rate gradually decreases and becomes negligible after approximately 3 to 4 months, depending on the compound.

Emissions from the first phase are estimated using the following expression:

$$E_1 = 1.37 \times 10^{-3} A e^{(0.4668t)} \quad (1)$$

where:

- E_1 = naphthalene emissions in lb/ft² of effective treated surface area,
- A = effective surface area in ft² of the treated wood (i.e., the surface area of the wood that is open and from which the creosote constituents can be released), and
- t = time in days since the wood was removed from the retort.

Integrating over the first 6 hours, this equation reduces to the following:

$$E_1 = 0.000363A \quad (2)$$

where:

E_1 and A are as defined above.

Emissions from the second phase can be estimated as follows:

$$E_2 = 2.78 \times 10^{-3} A e^{(-2.435t)} \quad (3)$$

where: E_2 = naphthalene emissions in lb/ft² of effective treated surface area, and t and A are as defined previously.

Integrating over the next 18 hours, this equation reduces to the following:

$$E_2 = 0.000521A \quad (4)$$

where: E_2 and A are as defined previously.

Emissions from the third phase can be estimated as follows:

$$E_3 = 2.53 \times 10^{-4} A e^{(-0.0436t)} \quad (5)$$

where: E_3 = naphthalene emissions in lb/ft² of effective treated surface area, and A and t are as defined previously.

Integrating from day 1 to day x, the equation reduces to the following:

$$E_3 = 0.00581A(e^{(-0.0436)} - e^{(-0.0436x)}) \quad (6)$$

where: E_3 and A are as defined previously, and
t = time in days from the time the retort was opened to day x.

The report also makes that the assumption that emissions primarily are a function of vapor pressure, which is driven by temperature. Accordingly, Antoine's vapor pressure equation can be used to develop a temperature correction factor. Using the average monthly temperature of 27°C (80°F) at the test site, the expression for the correction factor for naphthalene is as follows:

$$TCF_{\text{naph}} = e^{-11.161 \left(\frac{1}{T + 460} - \frac{1}{540} \right)} \quad (7)$$

where:

TCF_{naph} = temperature correction factor for naphthalene, and
T = average temperature in °F.

Reference 17 provides information that supplements the emission test report (Reference 15). Most notably, Reference 17 provides the corrected sampling times for each test run. These times differ from those used in the Reference 16 study. Because the sampling times were used in the linear regression equations, the differences in the times are significant.

A review of the emission and sampling time data indicates a trend of increasing emission with time of day, as would be expected if emissions are a function of ambient temperature. The models reported in Reference 16 do not account for the apparent confounding effect of ambient temperature on emissions. To minimize the ambient temperature effect, new models were developed using as data points the average emission rates and average sampling times for the fresh poles, 1-day old poles, and 4-day old poles. In addition, two (rather than three) equations were developed: the first equation was developed using the fresh pole data and the Day 1 data, and the second equation was developed by modeling the data from Day 1 to Day 30. The same method was used to develop the equations as was used in the Reference 16 report; that is,

simple linear regressions of the natural logs of the emission rates were performed. In addition to the naphthalene data, the emission data for the other seven PAH's detected also were modeled. The resulting equations for emissions over the first day following removal from the retort are of the following form:

$$E_{p1} = AC_{p1} (1 - e^{-x_{p1}}) \quad (8)$$

where:

- E_{p1} = emission factor for pollutant p for the first day in pounds per thousand square foot of effective treated wood surface area (lb/1,000 ft²),
- A = effective surface area of treated wood in thousands of square feet (1,000 ft²),
- C_{p1} = constant for pollutant p for the first day, and
- x_{p1} = exponential term for pollutant p for the first day.

Emissions for subsequent days up to Day "t" are of the following form:

$$E_{p2} = AC_{p2}(e^{-x_{p2}} - e^{-x_{p2}t}) \quad (9)$$

where:

- E_{p2} = emission factor for pollutant p for the first day in pounds per thousand square foot of effective treated wood surface area (lb/1,000 ft²),
- A = effective surface area of treated wood in thousands of square feet (1,000 ft²),
- C_{p2} = constant for pollutant p for the subsequent days up to Day "t," and
- x_{p2} = exponential term for pollutant p for the subsequent days up to Day "t."

The values of these variables for each of the eight PAH's are presented in Table 4-4. For example, the equation for estimating the naphthalene emission factor for Day 1 emissions is:

$$E_{naph1} = 0.839A(1 - e^{-2.106}) = 0.74A \quad (10)$$

where:

- E_{naph1} = emission factor for naphthalene for the first day in lb/1,000 ft², and
- A = effective surface area of treated wood in thousands of square feet (1,000 ft²).

The equation for estimating the naphthalene emission factor for emissions from Day 1 to Day "t" is:

$$E_{naph2} = 5.78A(e^{-0.0357} - e^{-0.0357t}) \quad (11)$$

where:

- E_{naph2} = emission factor for naphthalene in lb/1,000 ft² for the period from Day 1 to Day "t," and
- A = effective surface area of treated wood in thousands of square feet (1,000 ft²).

Equations 10 and 11 can be combined to give the total cumulative naphthalene emissions as follows:

$$\begin{aligned} E_{naphthalene} &= 0.74A + 5.78A(e^{-0.0357} - e^{-0.0357t}) \\ &= 0.74A + 5.78A(0.965 - e^{-0.0357t}) \\ &= 0.74A + 5.58A - 5.78Ae^{-0.0357t} \end{aligned}$$

$$E_{\text{naphthalene}} = (6.31 - 5.78e^{-0.0357t})A \quad (12)$$

Table 4-5 shows the comparable equations for cumulative emissions for each of the eight PAH's, and Table 4-6 shows the solutions to the equations for time periods up to 300 days. For example, the cumulative emission factor for fluorene from creosote-treated wood that has been stored for 120 days is 1.67 lb/1,000 ft². The values shown in Table 4-5 for each of the eight PAH's are presented graphically in Figures 4-1 to 4-8. The temperature correction factor for naphthalene, which can be determined using Equation 7, is shown graphically in Figure 4-9. It should be noted that this correction factor applies only to naphthalene emissions. Reference 20 presents a temperature correction factor for creosote as a whole. That factor can be expressed as:

$$TCF_{\text{creosote}} = e^{-8.531\left(\frac{1}{T + 460} - \frac{1}{540}\right)} \quad (13)$$

where:

TCF_{creosote} = temperature correction factor for creosote, and
 T = average temperature in °F.

As depicted in Figures 4-1 to 4-8, the fugitive emission rates decrease with time, and become negligible after a period of 2 to 4 months. Beyond those time periods, cumulative fugitive emissions can be estimated using the constant in each of the equations in Table 4-5. These constants represent the maximum emission factors for emissions that result from the open storage of creosote-treated wood. These maximum emission factors, rounded to two significant figures, also are listed separately in Table 4-5. For example, the maximum emission factor for naphthalene emissions (rounded to two significant figures) is 6.3 lb/1,000 ft²; the maximum emission factor for fluorene emissions (rounded to two significant figures) is 1.7 lb/1,000 ft². To adjust the naphthalene emission factor for temperature, the factor should be multiplied by the correction factor represented by Equation 7 and depicted graphically in Figure 4-9. For example, the correction factor for an average temperature of 70°F is 0.68, and the adjusted emission factor for the maximum naphthalene emissions is:

$$6.3 \times 0.68 = 4.3 \text{ lb/1,000 ft}^2$$

4.2.1.6. Reference 18. This reference is a guidance document prepared by AWPI to help wood preserving facilities determine the applicability and content of reporting requirements for the Toxic Release Inventory System under Title III of the Superfund Amendments and Reauthorization Act (SARA). The document includes methods for estimating process and fugitive emissions from wood preserving facilities. However, all of the methods presented are based on estimation methods for other industries. Fugitive emission rates for pump seals, valves flanges, seals, and connections are based on emission factors developed for the synthetic organic chemical manufacturing industry (SOCMI). The emission factors for creosote are assumed to be 10 percent of the corresponding factor for SOCMI sources, and the factors for pentachlorophenol are assumed to be 1 percent of the corresponding SOCMI factors. Process emissions for retort door opening, tank venting, and vacuum exhaust are based on the vapor weight fractions of the wood preservative constituents. This method is addressed in AP-42 Section 7.1.4, HAP Speciation Methodology. Because the estimation methods presented in Reference 18 are based on estimation methods for other industries, the methods have not been incorporated in the AP-42 section on wood preserving.

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

A search of the XATEF data base revealed 37 emission factors for wood preserving. Fifteen of the emission factors are based on Reference 3. This reference is reviewed above in Section 4.2.1.1 of this report.

Twenty-one of the 37 emission factors are based on an Office of Research and Development report that includes an assessment of fugitive emissions from one unspecified wood treating plant (B. DaRos, *et al.*, *Emissions and Residue Values from Waste Disposal During Wood Preserving*, prepared by Acurex Corporation, EPA-600/2-82-062, U. S. Environmental Protection Agency, Cincinnati, OH, April 1982). Nine of these 21 emission factors are for the thermal evaporation of wastewater. These emission factors have not been incorporated into the draft AP-42 Section 10.8 because they are more appropriate for AP-42 Chapter 4, Evaporation Source Losses. Six more of these 21 emission factors are for waste incineration. These sludges are classified as hazardous waste, hence their incineration, which is addressed in AP-42 Chapter 2, Solid Waste Disposal. Remaining are three emission factors for creosote treating cylinder fugitive emissions and three emission factors for pentachlorophenol treating cylinder fugitive emissions. These six emission factors are given in concentration units (milligrams per standard cubic meter of gas leaked). The report states that it was not feasible to quantify mass emission rates due to the large fluctuation in ambient air dilution caused by changing wind speed and direction. For this reason, these emission factors have not been incorporated into the draft AP-42 Section 10.8.

The remaining emission factor is referenced to a locating and estimating document (*Locating and Estimating Air Emissions from Sources of Chlorobenzenes*, EPA-450/4-84-007m, U. S. Environmental Protection Agency, Research Triangle Park, NC, 1987). This document does not include emission factors for wood preserving operations. However, it does state that where preservatives containing 1,2,4-trichlorobenzene are used, an estimated 1 percent of the 1,2,4-trichlorobenzene is emitted to the atmosphere during application and handling. Because the reference does not include a true emission factor, this XATEF emission factor was not incorporated into the draft AP-42 Section 10.8.

The SPECIATE data base includes emission factors for a number of speciated VOC's from wood preserving. However, the emission factors are all surrogates based on averages of all emission profiles. For that reason, these emission factors have not been incorporated into the draft AP-42 Section 10.8.

The SPECIATE data base includes emission factors for speciated PM from wood preserving. However, the emission factors are all surrogates based on averages for the wood products industry as a whole. For that reason, these emission factors have not been incorporated into the draft AP-42 Section 10.8.

4.2.3 Results of Data Analysis

4.2.3.1 Process Emission Factors. The test data for emissions from creosote wood preserving operations are presented in Tables 4-7 to 4-11. Table 4-12 is a summary of the creosote wood preserving data. The four steps in the empty cell treatment process during which emissions occur are: conditioning, preservative filling/air release, preservative return/blowback, and vacuum. For none of the pollutants listed in Table 4-12 are there complete data for all four of these steps. For example, there are VOC emission data for the conditioning (Boulton) and preservative return/blowback steps only; for naphthalene, there are emission data for the conditioning (Boulton), preservative filling/air release, and vacuum steps only. To provide an estimate of the emission factors for the complete empty cell process, these data gaps for each pollutant were filled using ratios of the emission factors for process steps for which data were available as follows:

- (1) For conditioning, the emission factor data gaps were filled by dividing the preservative filling/air release value by the average of the ratios of the preservative filling/air release

values to the conditioning values; this average equals 0.0337. For example, for fluoranthene, the conditioning value was estimated to be:

$$(2.0 \times 10^{-8}) / (0.0337) = 5.9 \times 10^{-7}$$

- (2) For preservative filling/air release, the emission factor data gaps were filled by multiplying the preservative filling/air release value by the average of the ratios of the preservative filling/air release values to the conditioning values; this average equals 0.0337. For example, for VOC, the preservative filling/air release value was estimated to be:

$$(5.1 \times 10^{-3}) \times (0.0337) = 1.7 \times 10^{-4}$$

- (3) For preservative return/blowback, the emission factor data gaps were filled by multiplying the conditioning value by the ratio of the preservative return/blowback value to the conditioning value for VOC; this ratio equals 0.0131. For example, for anthracene, the preservative return/blowback value was estimated to be:

$$(1.1 \times 10^{-7}) \times (0.0131) = 1.4 \times 10^{-9}$$

- (4) For the vacuum step, the emission factor data gaps were filled by multiplying the preservative filling/air release value by the average of the ratios of the preservative filling/air release values to the vacuum step values; this average equals 2.93. For example, for pyrene, the vacuum step value was estimated to be:

$$(1.7 \times 10^{-8}) \times (2.93) = 5.0 \times 10^{-8}$$

Table 4-13 shows the emission factors for each step in the process for each pollutant for which test data were available. Table 4-14 shows the same table with the additional emission factors that were estimated using the gap-filling procedures described above. Table 4-14 also shows the emission factors for the total treatment process with and without conditioning by the Boulton process. These emission factors for the total process are simply the sum of the factors for the individual steps in the process.

Table 4-15 summarizes the available test data for CCA treatment operations. Table 4-16 presents the candidate emission factors for the overall creosote wood preserving process. Table 4-17 presents the candidate emission factors for the CCA treatment process.

For most of the process steps sampled and pollutants quantified, data were available from a single emission test. However, for some speciated organics, emission data for creosote wood preserving were available from both References 10 and 13. For most compounds, the emission factors developed from the Reference 10 data were 1 to 2 orders of magnitude greater than the corresponding factors developed from Reference 13 data. Because the emission factors developed from the Reference 10 data are based on several assumptions and are inconsistent with the data from the other test reports reviewed, the factors developed from the Reference 10 data were not used to develop candidate emission factors for creosote wood preserving. In the case of CCA wood preserving, the Reference 10 are the only data found. In the absence of other data, the factors developed from Reference 10 for CCA wood preserving emissions were incorporated into the AP-42 section.

Because all of the candidate emission factors are based on one emission test, and, with the exception of one B-rated data set, the data sets are rated C or D, the emission factors developed from the data all are assigned a rating of E.

4.2.3.2 Fugitive Emissions. The basis for the fugitive emission equations for storage of creosote-treated wood, as presented in Table 4-5 and presented graphically in Figures 4-1 to 4-8, are the emission test documented in Reference 15 and the related report (Reference 16). That emission test was designed to quantify emissions from treated wood that was exposed on all surfaces. In practice, treated wood is stacked in such a way that a significant amount of wood surface area is in contact with other pieces of treated wood and/or the ground or pad on which the wood is stacked. Furthermore, the enclosure in which the test pieces were located during the emission test was continuously exhausted with sweep air to ensure a quantifiable exhaust flow rate from the enclosure to the test point. This sweep air enhanced volatilization of creosote constituents from the test pieces and is not representative of air movement through a typical stack of treated wood. For these reasons, the equations presented in Table 4-5 and the figures are very likely to provide an overestimate of fugitive emissions from actual treated wood storage yards.

References 16 and 19 describe a method for estimating the effective surface area (i.e., the surface area that is open and free to release volatile compounds from the creosote-treated wood). According to those two documents, the effective surface area can be estimated as the outside (visible) surface area of the stack, assuming specific stacking configurations for crossties and poles. For crossties, the net result is an effective surface area that is approximately 10 percent of the total surface area of the wood (i.e., 10 percent of the sum of the individual surface area for each piece of treated wood in the stack). For poles, the proposed effective surface area is approximately 15 percent of the total surface area of the wood. Although Reference 19 proposes several reasons for why using the total surface area overestimates fugitive emissions, the document provides no data or calculations to substantiate that the authors' proposed method for determining effective surface areas for crossties and poles.

Using the total surface area of each piece of treated wood would undoubtedly provide an overestimate of fugitive emissions from yard storage. However, the effective surface area proposed in References 16 and 19 appears to result in an unreasonably low estimate of fugitive emissions. In the absence of a substantiated method for estimating the effective surface area, the equations presented in Table 4-5 have not been incorporated into the AP-42 section.

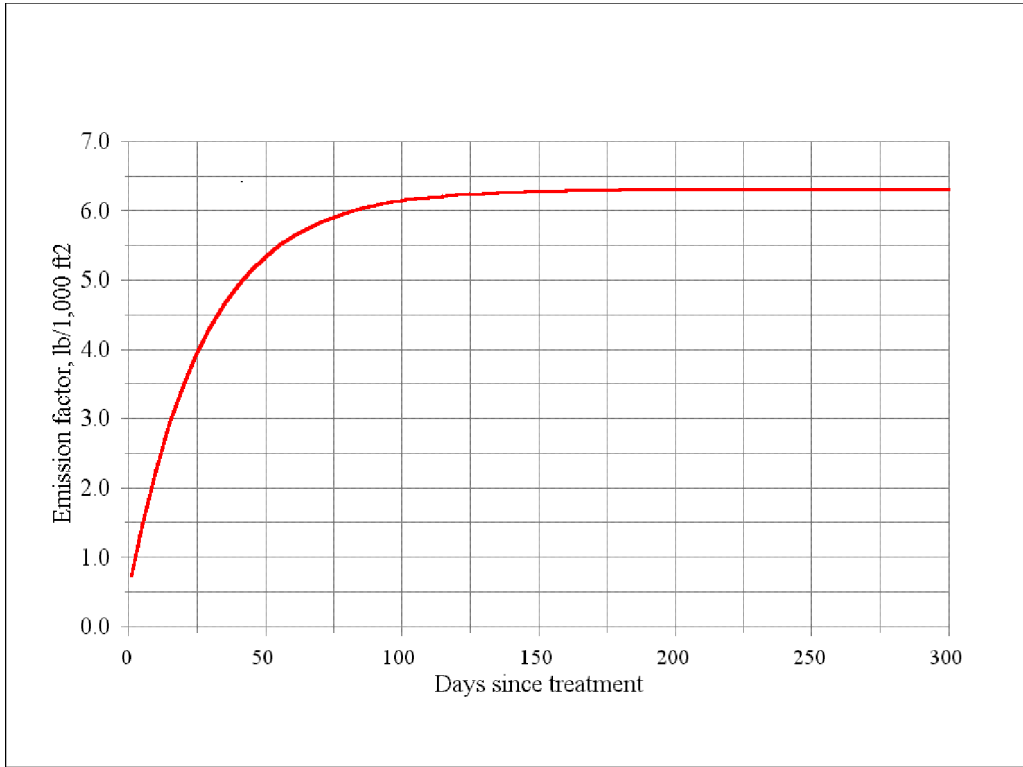


Figure 4-1. Naphthalene emissions from open storage of creosote-treated wood.

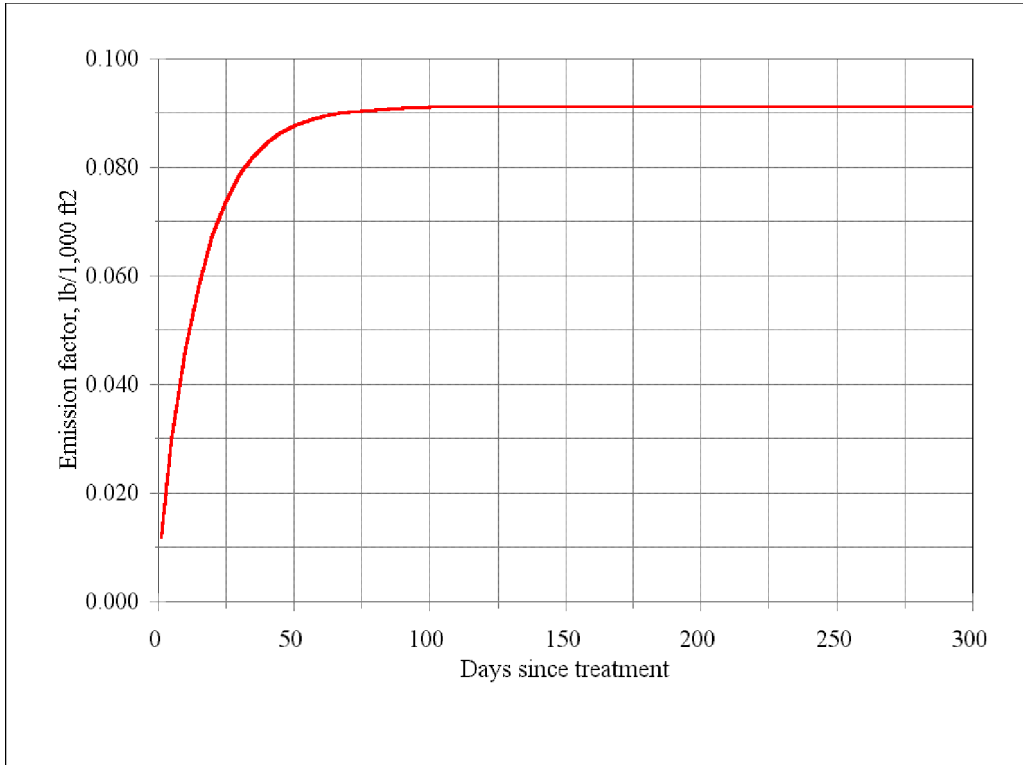


Figure 4-2. Acenaphthalene emissions from open storage of creosote-treated wood.

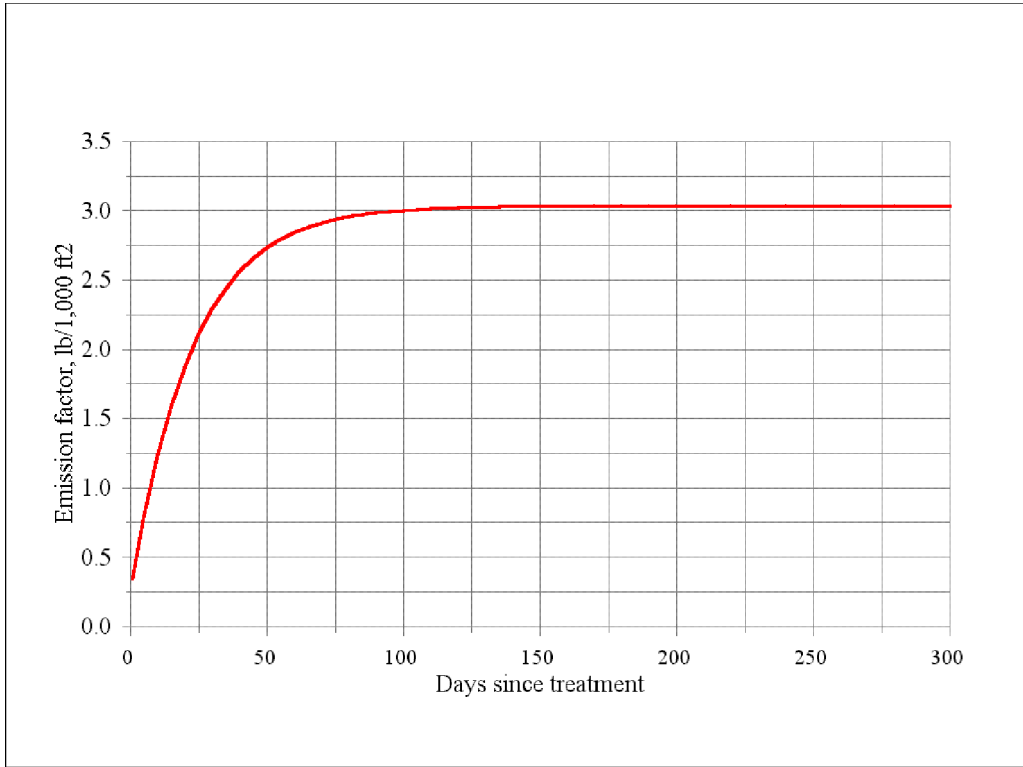


Figure 4-3. Acenaphthene emissions from open storage of creosote-treated wood.

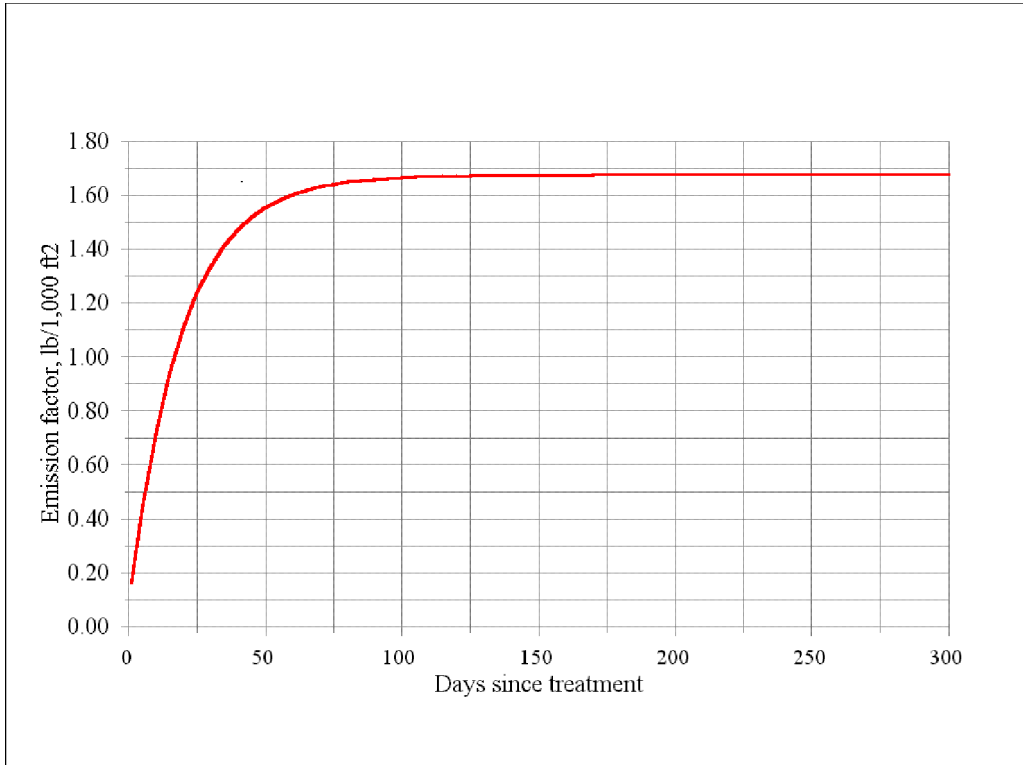


Figure 4-4. Fluorene emissions from open storage of creosote-treated wood.

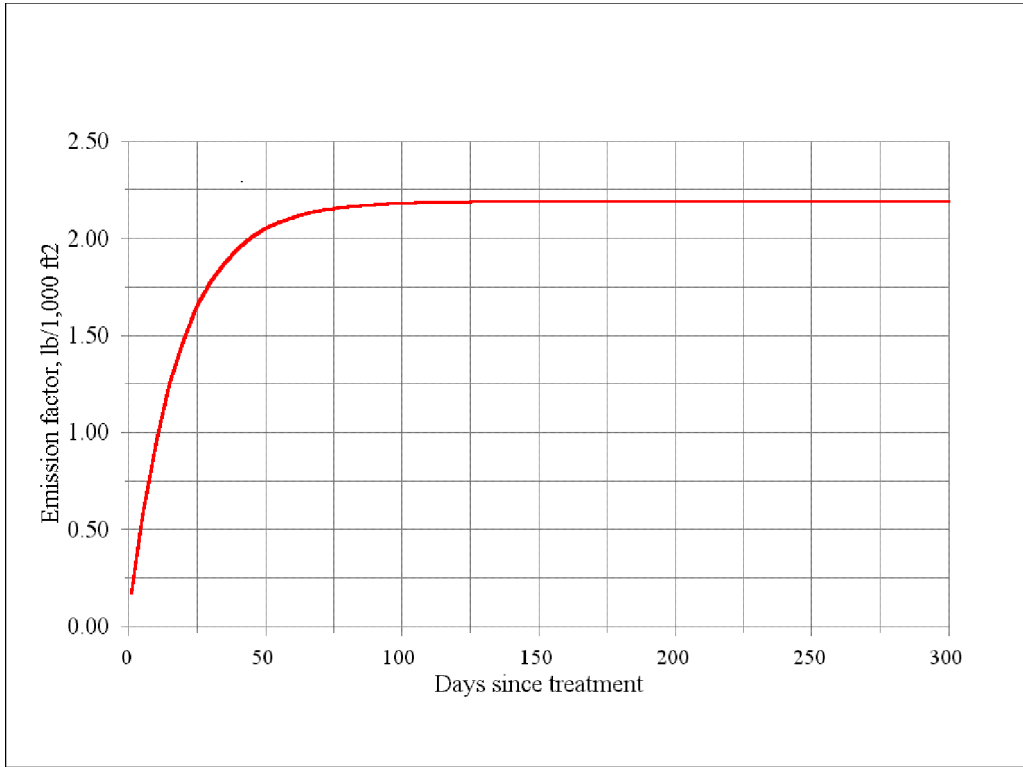


Figure 4-5. Phenanthrene emissions from open storage of creosote-treated wood.

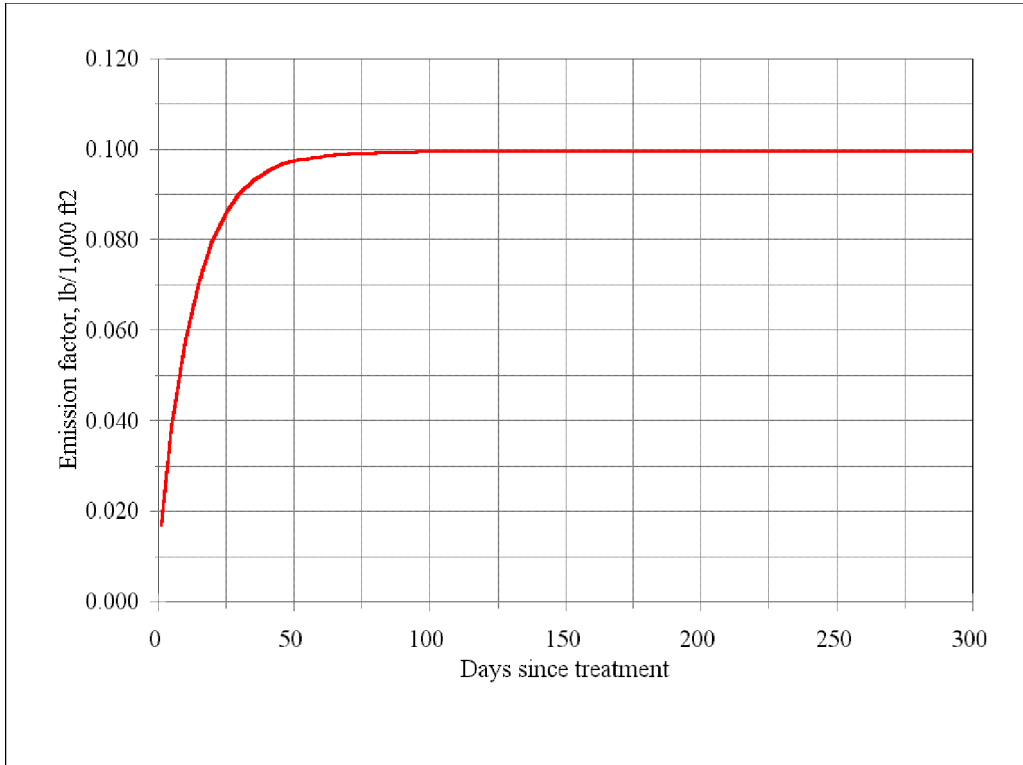


Figure 4-6. Anthracene emissions from open storage of creosote-treated wood.

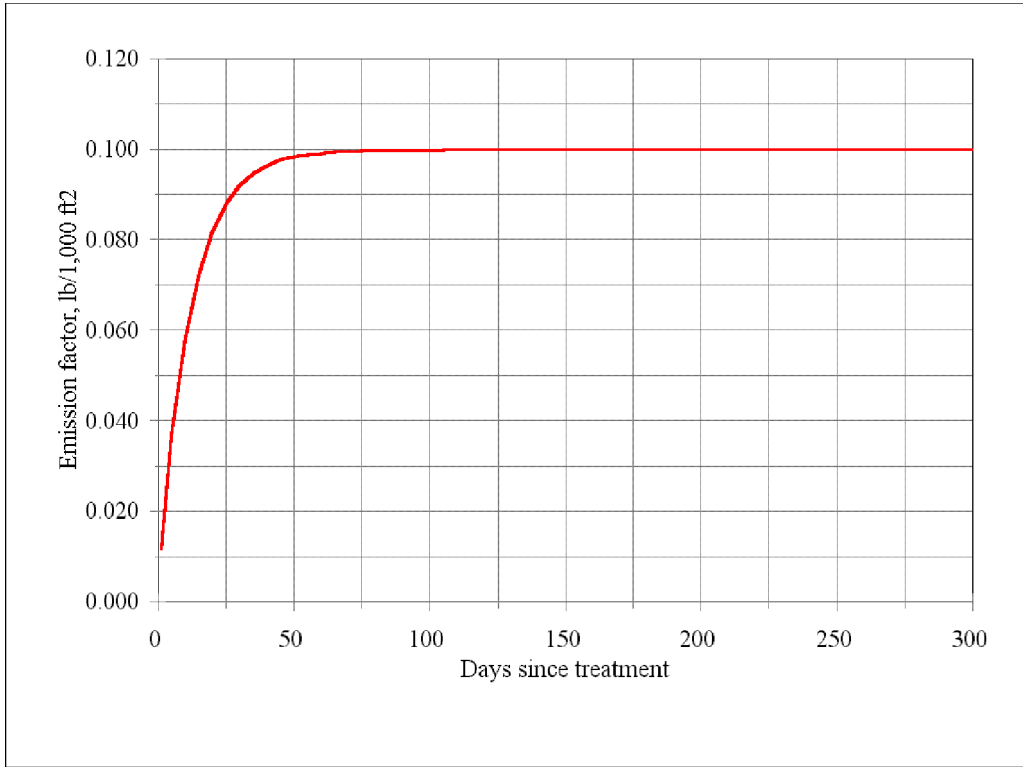


Figure 4-7. Fluoranthene emissions from open storage of creosote-treated wood.

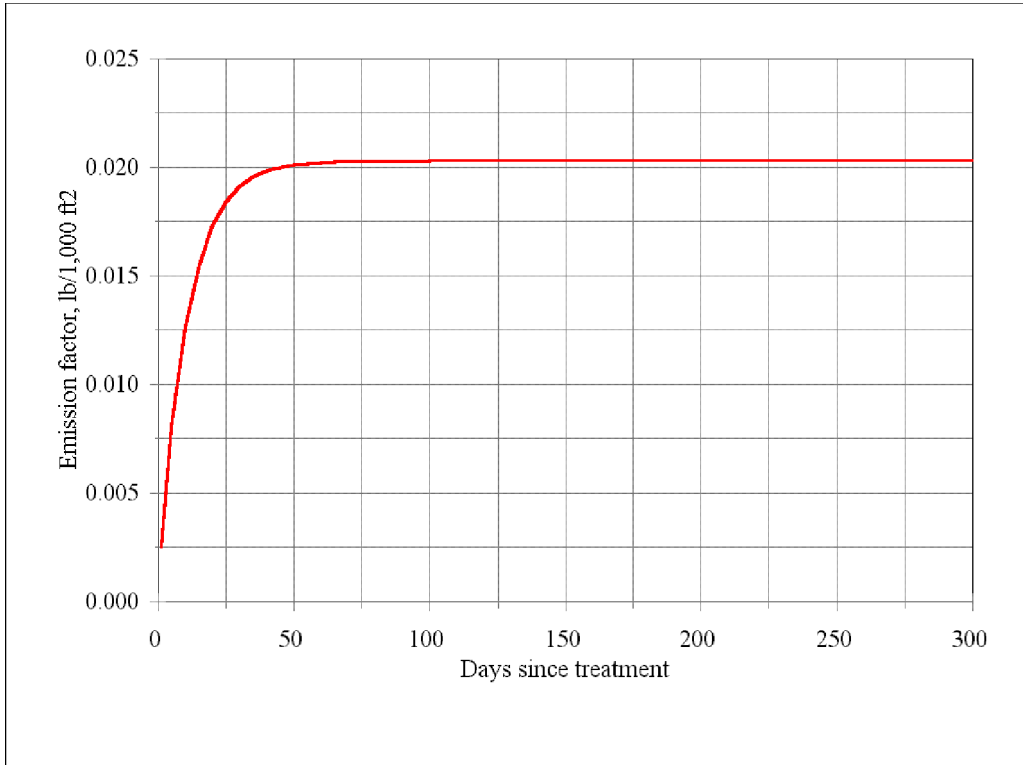


Figure 4-8. Pyrene emissions from open storage of creosote-treated wood.

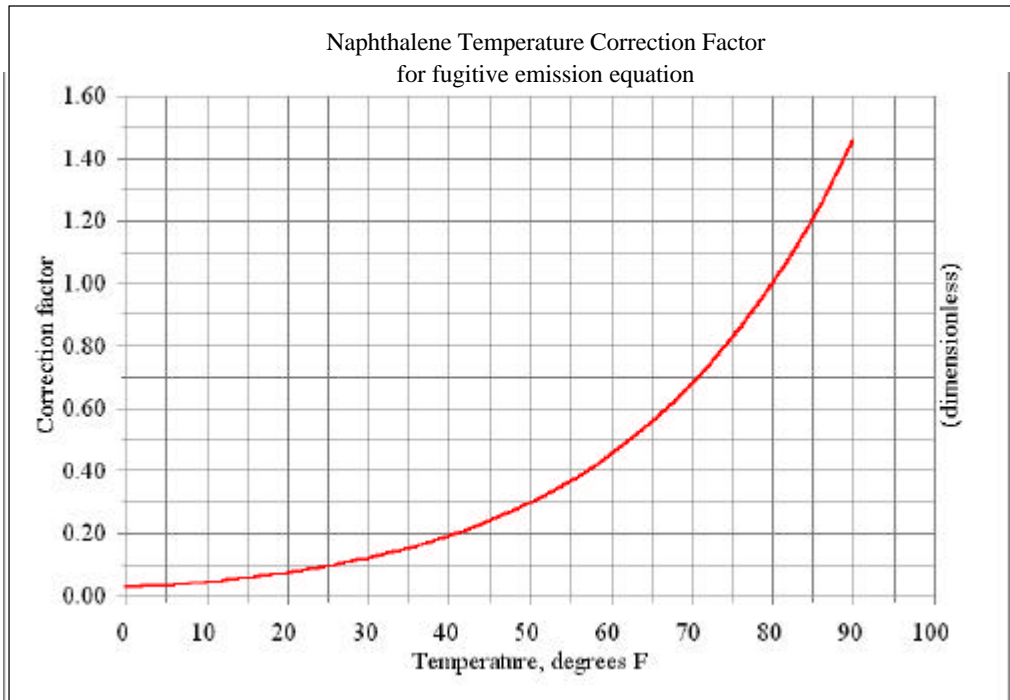


Figure 4-9. Naphthalene temperature correction factors for fugitive emission equation.

TABLE 4-1. REFERENCES FOR WOOD PRESERVING

Ref. No.	Citation
1	C. C. Vaught and R. L. Nicholson, <i>Evaluation of Emission Sources from Creosote Wood Treatment Operations</i> , EPA-450/3-89-028, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1989.
2	B. DaRos, <i>et al.</i> , <i>Emissions and Residue Values from Waste Disposal During Wood Preserving</i> , prepared by Acurex Corporation, EPA-600/2-82-062, U. S. Environmental Protection Agency, Cincinnati, OH, April 1982.
3	<i>Emission Test Report</i> , Air Toxics Sampling at Wyckoff, Inc., Bainbridge Island, Washington, prepared by Engineering Science, EPA-910/9-86-149, U. S. Environmental Protection Agency, March 1986.
4	<i>Report of Emissions Test: Koppers Industries Wood Fired Boiler, Florence, SC</i> , prepared for Koppers Industries, by ATEC Associates, Inc., October 8, 1991.
5	<i>Non-criteria Pollutant Emissions Calculations for Koppers Industries, Salem, VA</i> , prepared for Koppers Industries, by ETS, Inc., June 17, 1991.
6	<i>Assessment of the Fume Scrubber Operational Performance at Burke-Parsons-Bowlby, Dubois, PA</i> , prepared for Burke-Parsons-Bowlby, by Allied-Signal, Inc., Environmental Systems, May 1992.
7	<i>Determination of Air Toxic Emissions from Non-traditional Sources in the Puget Sound Region</i> , EPA-910/9-86-148, U. S. Environmental Protection Agency, Region X and Puget Sound Air Pollution Control Agency, Seattle, WA, by Engineering-Science, Inc., April 1986.
8	<i>Engineering Calculation of Pentachlorophenol Air Emissions at Wood Preserving Facilities</i> , prepared for Vulcan Chemicals, Birmingham, AL, by H.M. Rollins Company, Inc., August 31, 1992.
9	<i>Results of the September 1991 Air Emission Compliance Test on the Pole Treatment Facility at the Bell Lumber and Pole Plant in New Brighton, Minnesota</i> , prepared for Bell Lumber and Pole Company, by Interpoll Laboratories, Inc., October 24, 1991.
10	<i>Final Emission Data Report: Emission Testing Program at Koppers Superfund Site, Oroville, California</i> , prepared for U. S. Environmental Protection Agency, Region IX, by Ebasco Services Incorporated, December 1989.
11	<i>Wood Treatment Plant Emission Test Report, Kerr-McGee Chemical Corporation, Avoca, Pennsylvania, EMB Report 94-WDT-01</i> , U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1994.
12	<i>Wood Treatment Plant Emission Test Report, Burke-Parsons-Bowlby Corporation, DuBois, Pennsylvania, EMB Report 94-WDT-02</i> , U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1994.
13	<i>Koppers Industries, Incorporated, Pittsburgh, Pennsylvania, Susquehanna Wood Treating Facilities Vacuum Pump Emissions Study</i> , Chester Environmental, Pittsburgh, PA, April 1994.
14	<i>Gaseous Organic Compound Emission Study, Naphthalene Knock-out Tank and Water Scrubber, Birmingham Wood, Inc., Warrior, Alabama, Allied Signal, Inc., April 12 & 13, 1994</i> , TTL, Inc., Tuscaloosa, AL, May 1994.
15	<i>Koppers Industries, Inc., Oroville, CA, AB 2588 Emissions Test Program, Test Date: October 8 thru 12, 1990</i> , Best Environmental, Hayward, California, November 14, 1990.
16	<i>Calculated Emissions From Creosote-Treated Wood Products (Cross-Ties and Poles)</i> , AquaAeTer, Brentwood, Tennessee, and American Wood Preservers Institute, Vienna, Virginia, October 13, 1994.
17	Written communication from Steve Smith, Koppers Industries, Incorporated, Pittsburgh, Pennsylvania, to Rick Marinshaw, Midwest Research Institute, Cary, North Carolina, July 10, 1997.

TABLE 4-1. (continued)

Ref. No.	Citation
18	<i>TRI Reporting (Form R) Guidance Manual for Wood Preserving Facilities, 1995 Edition</i> , American Wood Preservers Institute, Vienna, Virginia, 1995.
19	Personal communication from Michael R. Corn and Douglas S. Smith, AquAeTer, Incorporated, to Martin Wikstrom, American Wood Preservers Institute, December 28, 1994.
20	Personal communication from Mike Pierce and Michael R. Corn, AquAeTer, Incorporated, to George Parris, American Wood preservers Institute, September 17, 1998.

TABLE 4-2. REFERENCES REJECTED FOR EMISSION FACTOR DEVELOPMENT

Ref. No.	Reason(s) for rejection
1	No process data; emission estimates appear to be based on material balance approach.
2	No emission rates; large fluctuations in process flow rates precluded conversion from concentrations to emission rates.
3	Reported volumetric air flows are erroneous and cross-contamination of samples occurred.
4	Test not conducted on wood preserving process source; insufficient process data to allow calculation of an emission factor.
5	Emission estimates based on testing at another facility; no test data presented.
6	Insufficient process data to allow calculation of an emission factor.
7	Insufficient process data to allow calculation of an emission factor.
8	No test data; includes only engineering estimates of emissions.
9	Insufficient process data to allow calculation of an emission factor.
12	Contaminated creosote preservative used during test.
14	Process rates not provided and emissions not representative of a single step in the wood preserving process.
18	Emission estimation methods based on sources addressed in other AP-42 sections; does not present test data.
19	Does not contain emission data.
20	Does not contain emission data.

TABLE 4-3. COMPOUNDS DETECTED
IN CREOSOTE SAMPLES^a

Compound	Concentration, $\mu\text{g/ml}$
Naphthalene ^b	223.44
2-Methylnaphthalene	150.18
Acenaphthylene	216.12
Dibenzofuran ^b	131.87
Fluorene	128.21
Phenanthrene	300.37
Anthracene	40.29
Fluoranthene	227.11
Pyrene	163.50
Chrysene	51.28
Benzo(a)anthracene	40.29
Benzo(b)fluoranthene	21.98
Benzo(k)fluoranthene	13.55
Indeno(1,2,3-cd)pyrene	16.12
Biphenyl ^b	36.63
Quinoline ^b	36.63

^aReference 11.

^bListed as HAP in Clean Air Act.

TABLE 4-4. PARAMETER VALUES FOR ESTIMATING EMISSION FACTORS FOR FUGITIVE EMISSIONS FROM CREOSOTE-TREATED WOOD

Parameter ^a	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene
C _{p1}	0.839	0.0142	0.4041	0.2127	0.2860	113.5	0.02209	0.01612
x _{p1}	-2.1066	-1.885	-1.897	-1.451	-0.9488	-0.0001491	-0.7661	-0.1693
C _{p2}	5.775	0.08441	2.815	1.593	2.129	0.08906	0.09568	0.01954
x _{p2}	-0.0357	-0.0633	-0.0446	-0.0515	-0.0544	-0.0759	-0.0838	-0.0939

^aVariables used in Equations 8 and 9.

TABLE 4-5. EMISSION FACTOR EQUATIONS FOR CUMULATIVE EMISSIONS OF PAH'S FROM CREOSOTE-TREATED WOOD STORAGE

Pollutant	Emission factor equation, lb/1,000 ft ²	Emission factor for maximum emissions, lb/1,000ft ²
Naphthalene	$E = 6.31 - 5.78e^{-0.0357t}$	6.3
Acenaphthylene	$E = 0.0912 - 0.0844e^{-0.0633t}$	0.091
Acenaphthene	$E = 3.04 - 2.82e^{-0.0446t}$	3.0
Fluorene	$E = 1.68 - 1.59e^{-0.0515t}$	1.7
Phenanthrene	$E = 2.19 - 2.13e^{-0.0544t}$	2.2
Anthracene	$E = 0.0995 - 0.0891e^{-0.0759t}$	0.10
Fluoranthene	$E = 0.0998 - 0.0957e^{-0.0838t}$	0.10
Pyrene	$E = 0.0203 - 0.0195e^{-0.0939t}$	0.020

E = emission factor in units of lb/1,000 ft² of effective surface area of treated wood. t = number of days since removal from retort.

TABLE 4-6. EMISSION FACTORS FOR PAH'S FROM OPEN STORAGE OF CREOSOTE-TREATED WOOD

Day	Emission factor, lb/1,000 ft ²							
	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluroanthene	Pyrene
1	0.74	0.0120	0.34	0.16	0.18	0.0169	0.0118	0.0025
5	1.48	0.0297	0.78	0.44	0.57	0.0385	0.0369	0.0081
10	2.27	0.0464	1.23	0.72	0.96	0.0578	0.0584	0.0127
15	2.93	0.0586	1.59	0.94	1.25	0.0709	0.0726	0.0155
20	3.48	0.0674	1.88	1.11	1.47	0.0799	0.0819	0.0173
25	3.94	0.0739	2.11	1.24	1.65	0.0861	0.0880	0.0184
30	4.33	0.0786	2.30	1.34	1.78	0.0903	0.0921	0.0191
35	4.65	0.0820	2.45	1.41	1.87	0.0932	0.0947	0.0196
40	4.92	0.0845	2.56	1.47	1.95	0.0952	0.0965	0.0198
45	5.15	0.0863	2.66	1.52	2.01	0.0965	0.0976	0.0200
50	5.34	0.0877	2.73	1.55	2.05	0.0975	0.0984	0.0201
60	5.63	0.0893	2.84	1.60	2.11	0.0985	0.0992	0.0202
70	5.83	0.0902	2.91	1.63	2.14	0.0990	0.0995	0.0203
80	5.98	0.0907	2.96	1.65	2.16	0.0993	0.0997	0.0203
90	6.08	0.0909	2.99	1.66	2.18	0.0994	0.0998	0.0203
100	6.15	0.0911	3.00	1.67	2.18	0.0994	0.0998	0.0203
120	6.23	0.0912	3.02	1.67	2.19	0.0995	0.0998	0.0203
140	6.27	0.0912	3.03	1.67	2.19	0.0995	0.0998	0.0203
160	6.29	0.0912	3.03	1.68	2.19	0.0995	0.0998	0.0203
180	6.30	0.0912	3.04	1.68	2.19	0.0995	0.0998	0.0203
200	6.31	0.0912	3.04	1.68	2.19	0.0995	0.0998	0.0203
250	6.31	0.0912	3.04	1.68	2.19	0.0995	0.0998	0.0203
300	6.31	0.0912	3.04	1.68	2.19	0.0995	0.0998	0.0203

TABLE 4-7. SUMMARY OF TEST DATA FOR EMPTY-CELL CREOSOTE WOOD PRESERVING--VACUUM SYSTEM/CONDITIONING (BOULTON) CYCLE

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/m ³ (lb/ft ³)	Average, kg/m ³ (lb/ft ³)	
N/K	Naphthalene	3	D	Not reported ^a	0.00049 (3.1 x 10 ⁻⁵)	10
N/K	2-Methylnaphthalene	3	D	Not reported ^a	0.00060 (3.7 x 10 ⁻⁵)	10
None	VOC	1	C	Not applicable	0.082 (0.0051)	11
None	Carbazole	2	C	1.5 x 10 ⁻⁵ - 6.6 x 10 ⁻⁵ (9.4 x 10 ⁻⁷ - 4.1 x 10 ⁻⁶)	4.1 x 10 ⁻⁵ (2.5 x 10 ⁻⁶)	13
None	Naphthalene	2	C	3.4 x 10 ⁻⁴ - 2.0 x 10 ⁻³ (2.1 x 10 ⁻⁵ - 1.3 x 10 ⁻⁴)	0.0012 (7.4 x 10 ⁻⁵)	13
None	Acenaphthylene	2	C	5.7 x 10 ⁻⁵ - 7.6 x 10 ⁻⁴ (3.6 x 10 ⁻⁶ - 4.7 x 10 ⁻⁵)	0.00041 (2.6 x 10 ⁻⁵)	13
None	Acenaphthene	2	C	5.7 x 10 ⁻⁵ - 2.4 x 10 ⁻⁴ (3.6 x 10 ⁻⁶ - 1.5 x 10 ⁻⁵)	0.00015 (9.3 x 10 ⁻⁶)	13
None	Dibenzofuran	2	C	6.6 x 10 ⁻⁵ - 1.0 x 10 ⁻³ (4.1 x 10 ⁻⁶ - 6.2 x 10 ⁻⁵)	0.00053 (3.3 x 10 ⁻⁵)	13
None	Fluorene	2	C	5.4 x 10 ⁻⁵ - 6.8 x 10 ⁻⁵ (3.4 x 10 ⁻⁶ - 4.2 x 10 ⁻⁶)	6.1 x 10 ⁻⁵ (3.8 x 10 ⁻⁶)	13
None	Phenanthrene	2	C	1.8 x 10 ⁻⁵ - 3.5 x 10 ⁻⁵ (1.1 x 10 ⁻⁷ - 2.1 x 10 ⁻⁶)	2.6 x 10 ⁻⁵ (1.6 x 10 ⁻⁶)	13
None	Anthracene	2	C	4.7 x 10 ⁻⁷ - 3.0 x 10 ⁻⁶ (2.9 x 10 ⁻⁸ - 1.9 x 10 ⁻⁷)	1.7 x 10 ⁻⁶ (1.1 x 10 ⁻⁷)	13
None	Chrysene	2	C	8.5 x 10 ⁻⁷ - 1.0 x 10 ⁻⁶ (5.3 x 10 ⁻⁸ - 6.5 x 10 ⁻⁸)	9.5 x 10 ⁻⁷ (5.9 x 10 ⁻⁸)	13

N/K = not known

kg/m³ = kg of pollutant per cubic meter of wood treated

lb/ft³ = lb of pollutant per cubic foot of wood treated

^aAlthough three runs were made, only the average emission rate for each pollutant was reported in the reference. Therefore, only the average emission factor could be calculated.

TABLE 4-8. SUMMARY OF TEST DATA FOR EMPTY-CELL CREOSOTE WOOD PRESERVING--VACUUM SYSTEM

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/m ³ (lb/ft ³)	Average, kg/m ³ (lb/ft ³)	
MAIN VACUUM STEP						
None	Naphthalene	1	C	Not applicable	4.8 x 10 ⁻⁵ (3.0 x 10 ⁻⁶)	13
None	Acenaphthylene	1	C	Not applicable	7.1 x 10 ⁻⁶ (4.4 x 10 ⁻⁷)	13
None	Dibenzofuran	1	C	Not applicable	1.6 x 10 ⁻⁵ (1.0 x 10 ⁻⁶)	13
None	Fluorene	1	C	Not applicable	3.6 x 10 ⁻⁷ (2.3 x 10 ⁻⁸)	13
None	Phenanthrene	1	C	Not applicable	3.4 x 10 ⁻⁶ (2.1 x 10 ⁻⁷)	13
None	Anthracene	1	C	Not applicable	6.2 x 10 ⁻⁸ (3.9 x 10 ⁻⁹)	13
None	Chrysene	1	C	Not applicable	5.5 x 10 ⁻⁸ (3.5 x 10 ⁻⁹)	13
ADDITIONAL VACUUM STEP (FOLLOWING STEAMING PROCESS)						
N/K	Naphthalene	3	D	Not reported ^a	0.0022 (0.00014)	10
N/K	2-Methylnaphthalene	3	D	Not reported ^a	0.0034 (0.00021)	10
N/K	Acenaphthene	3	D	Not reported ^a	0.00015 (9.4 x 10 ⁻⁶)	10
N/K	Fluorene	3	D	Not reported ^a	1.2 x 10 ⁻⁵ (7.5 x 10 ⁻⁷)	10
N/K	Phenanthrene	3	D	Not reported ^a	1.2 x 10 ⁻⁵ (7.5 x 10 ⁻⁷)	10

N/K = not known
 kg/m³ = kg of pollutant per cubic meter of wood treated
 lb/ft³ = lb of pollutant per cubic foot of wood treated

^aAlthough two or three runs were made, only the average emission rate for each pollutant was reported in the reference. Therefore, only the average emission factor could be calculated.

TABLE 4-9. SUMMARY OF TEST DATA FOR EMPTY-CELL CREOSOTE WOOD PRESERVING-- PRESERVATIVE RETURN/WORKING TANK VENT BLOWBACK

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/m ³ (lb/ft ³)	Average, kg/m ³ (lb/ft ³)	
N/K	Naphthalene	2	D	Not reported ^a	0.0018 (0.00011)	10
N/K	2-Methylnaphthalene	2	D	Not reported ^a	0.0016 (0.00010)	10
None	VOC	1	B	Not applicable	0.0011 (6.7 x 10 ⁻⁵)	11

N/K = not known

kg/m³ = kg of pollutant per cubic meter of wood treated

lb/ft³ = lb of pollutant per cubic foot of wood treated

^aOnly the average emission rate for each pollutant was reported in the reference. Therefore, only the average emission factor could be calculated.

TABLE 4-10. SUMMARY OF TEST DATA FOR EMPTY-CELL CREOSOTE WOOD PRESERVING--WORKING TANK VENT/STEAMING CYCLE

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/m ³ (lb/ft ³)	Average, kg/m ³ (lb/ft ³)	
N/K	Naphthalene	2	D	NA ^a	0.041 (0.0026)	10
N/K	2-Methylnaphthalene	2	D	NA ^a	0.049 (0.0031)	10
N/K	Acenaphthene	2	D	NA ^a	0.014 (0.00087)	10
N/K	Phenanthrene	2	D	NA ^a	0.0024 (0.00015)	10

N/K = not known

NA = data not available

kg/m³ = kg of pollutant per cubic meter of wood treated

lb/ft³ = lb of pollutant per cubic foot of wood treated

^aOnly the average emission rate for each pollutant was reported in the reference. Therefore, only the average emission factor could be calculated.

TABLE 4-11. SUMMARY OF TEST DATA FOR EMPTY-CELL CREOSOTE
WOOD PRESERVING--PRESERVATIVE FILLING/AIR RELEASE

Type of control	Pollutant	No. of test runs	Data rating	Emission factor, kg/m ³ (lb/ft ³)	Ref.No.
None	Naphthalene	1	C	9.9 x 10 ⁻⁶ (6.2 x 10 ⁻⁷)	13
None	Acenaphthene	1	C	2.0 x 10 ⁻⁶ (1.3 x 10 ⁻⁷)	13
None	Dibenzofuran	1	C	6.5 x 10 ⁻⁶ (4.1 x 10 ⁻⁷)	13
None	Fluorene	1	C	7.9 x 10 ⁻⁸ (4.9 x 10 ⁻⁹)	13
None	Phenanthrene	1	C	7.6 x 10 ⁻⁷ (4.8 x 10 ⁻⁸)	13
None	Anthracene	1	C	1.7 x 10 ⁻⁷ (1.1 x 10 ⁻⁸)	13
None	Fluoranthene	1	C	3.3 x 10 ⁻⁷ (2.0 x 10 ⁻⁸)	13
None	Pyrene	1	C	2.7 x 10 ⁻⁷ (1.7 x 10 ⁻⁸)	13
None	Benzo(a)anthracene	1	C	6.2 x 10 ⁻⁸ (3.9 x 10 ⁻⁹)	13
None	Chrysene	1	C	6.6 x 10 ⁻⁸ (4.1 x 10 ⁻⁹)	13
None	Benzo(b)fluoranthene	1	C	6.0 x 10 ⁻⁸ (3.7 x 10 ⁻⁹)	13
None	Benzo(k)fluoranthene	1	C	2.3 x 10 ⁻⁸ (1.4 x 10 ⁻⁹)	13
None	Benzo(a)pyrene	1	C	3.0 x 10 ⁻⁸ (1.9 x 10 ⁻⁹)	13

TABLE 4-12. SUMMARY OF EMISSION FACTORS FOR EMPTY-CELL CREOSOTE WOOD PRESERVING OPERATIONS^a

Source	CASRN	Pollutant	Emission factor		Ref. No.
			kg/m ³	lb/ft ³	
Conditioning (Boulton) cycle		VOC	0.082	0.0051	11
	83-32-9	Acenaphthene	0.00015	9.3 x 10 ⁻⁶	13
		Acenaphthylene	0.00041	2.6 x 10 ⁻⁵	13
	120-12-7	Anthracene	1.7 x 10 ⁻⁶	1.1 x 10 ⁻⁷	13
	86-74-8	Carbazole	4.1 x 10 ⁻⁵	2.5 x 10 ⁻⁶	13
	218-01-9	Chrysene	9.5 x 10 ⁻⁷	5.9 x 10 ⁻⁸	13
	132-64-9	Dibenzofuran	0.00053	3.3 x 10 ⁻⁵	13
	86-73-7	Fluorene	6.1 x 10 ⁻⁵	3.8 x 10 ⁻⁶	13
	91-20-3	Naphthalene	0.0012	7.5 x 10 ⁻⁵	13
	85-01-8	Phenanthrene	2.6 x 10 ⁻⁵	1.6 x 10 ⁻⁶	13
Preservative filling/air release	83-32-9	Acenaphthene	2.0 x 10 ⁻⁶	1.3 x 10 ⁻⁷	13
	120-12-7	Anthracene	1.7 x 10 ⁻⁷	1.1 x 10 ⁻⁸	13
		Benzo(a)anthracene	6.2 x 10 ⁻⁸	3.9 x 10 ⁻⁹	13
		Benzo(b)fluoranthene	6.0 x 10 ⁻⁸	3.7 x 10 ⁻⁹	13
		Benzo(k)fluoranthene	2.3 x 10 ⁻⁸	1.4 x 10 ⁻⁹	13
	50-32-8	Benzo(a)pyrene	3.0 x 10 ⁻⁸	1.9 x 10 ⁻⁹	13
	218-01-9	Chrysene	6.6 x 10 ⁻⁸	4.1 x 10 ⁻⁹	13
	132-64-9	Dibenzofuran	6.5 x 10 ⁻⁶	4.1 x 10 ⁻⁷	13
	206-44-0	Fluoranthene	3.3 x 10 ⁻⁷	2.0 x 10 ⁻⁸	13
	86-73-7	Fluorene	7.9 x 10 ⁻⁸	4.9 x 10 ⁻⁹	13
	91-20-3	Naphthalene	9.9 x 10 ⁻⁶	6.2 x 10 ⁻⁷	13
	85-01-8	Phenanthrene	7.6 x 10 ⁻⁷	4.8 x 10 ⁻⁸	13
	129-00-0	Pyrene	2.7 x 10 ⁻⁷	1.7 x 10 ⁻⁸	13
Preservative return/ working tank vent blowback		VOC	0.0011	6.7 x 10 ⁻⁵	11
Vacuum cycle		Acenaphthylene	7.1 x 10 ⁻⁶	4.4 x 10 ⁻⁷	13
	120-12-7	Anthracene	6.2 x 10 ⁻⁸	3.9 x 10 ⁻⁹	13
	218-01-9	Chrysene	5.5 x 10 ⁻⁸	3.5 x 10 ⁻⁹	13
	132-64-9	Dibenzofuran	1.6 x 10 ⁻⁵	1.0 x 10 ⁻⁶	13
	86-73-7	Fluorene	3.6 x 10 ⁻⁷	2.3 x 10 ⁻⁸	13
	91-20-3	Naphthalene	4.8 x 10 ⁻⁵	3.0 x 10 ⁻⁶	13
	85-01-8	Phenanthrene	3.4 x 10 ⁻⁶	2.1 x 10 ⁻⁷	13

^a For empty-cell process. All emission factors rated E. Factors represent uncontrolled emissions. Emission factor units are kilograms per cubic meter and pounds per cubic foot of wood treated. CASRN = Chemical Abstract Services Registry Number.

TABLE 4-13. SUMMARY OF EMISSION FACTORS FOR EMPTY-CELL CREOSOTE WOOD PRESERVING SHOWING DATA GAPS^a

Pollutant	Conditioning by Boulton process ^b	Preservative filling/ air release	Preservative return/ blowback	Vacuum	Additional vacuum (optional)	Total, with conditioning by Boulton process ^b	Total, without conditioning
VOC	5.1×10^{-3}		6.7×10^{-5}				
Acenaphthene	9.3×10^{-6}	1.3×10^{-7}					
Acenaphthylene	2.6×10^{-5}			4.4×10^{-7}			
Anthracene	1.1×10^{-7}	1.1×10^{-8}		3.9×10^{-9}			
Benzo(a)anthracene		3.9×10^{-9}					
Benzo(b)fluoranthene		3.7×10^{-9}					
Benzo(k)fluoranthene		1.4×10^{-9}					
Benzo(a)pyrene		1.9×10^{-9}					
Carbazole	2.5×10^{-6}						
Chrysene	5.9×10^{-8}	4.1×10^{-9}		3.5×10^{-9}			
Dibenzofuran	3.3×10^{-5}	4.1×10^{-7}		1.0×10^{-6}			
Fluoranthene		2.0×10^{-8}					
Fluorene	3.8×10^{-6}	4.9×10^{-9}		2.3×10^{-8}			
Naphthalene	7.4×10^{-5}	6.2×10^{-7}		3.0×10^{-6}			
Phenanthrene	1.6×10^{-6}	4.8×10^{-8}		2.1×10^{-7}			
Pyrene		1.7×10^{-8}					

^aFactors in units of lb/ft³ of wood treated. References 11 and 13.

^bDoes not include emissions from preservative return/blowback associated with Boulton process.

TABLE 4-14. SUMMARY OF COMBINED EMISSION FACTORS FOR EMPTY-CELL CREOSOTE WOOD PRESERVING^a

Pollutant	Conditioning by Boulton process ^b	Preservative filling/ air release	Preservative return/ blowback	Vacuum	Additional vacuum (optional)	Total, with conditioning by Boulton process ^b	Total, without conditioning
VOC	5.1×10^{-3}	1.7×10^{-4}	6.7×10^{-5}	5.0×10^{-4}		5.8×10^{-3}	7.4×10^{-4}
Acenaphthene	9.3×10^{-6}	1.3×10^{-7}	1.2×10^{-7}	3.8×10^{-7}		9.9×10^{-6}	6.3×10^{-7}
Acenaphthylene	2.6×10^{-5}	8.7×10^{-7}	3.4×10^{-7}	4.4×10^{-7}		2.8×10^{-5}	1.7×10^{-7}
Anthracene	1.1×10^{-7}	1.1×10^{-8}	1.4×10^{-9}	3.9×10^{-9}		1.3×10^{-7}	1.6×10^{-8}
Benzo(a)anthracene	1.2×10^{-7}	3.9×10^{-9}	1.5×10^{-9}	1.1×10^{-8}		1.3×10^{-7}	1.7×10^{-8}
Benzo(b)fluoranthene	1.1×10^{-7}	3.7×10^{-9}	1.4×10^{-9}	1.1×10^{-8}		1.3×10^{-7}	1.6×10^{-8}
Benzo(k)fluoranthene	4.2×10^{-8}	1.4×10^{-9}	5.5×10^{-10}	4.1×10^{-9}		4.8×10^{-8}	6.0×10^{-9}
Benzo(a)pyrene	5.6×10^{-8}	1.9×10^{-9}	7.4×10^{-10}	5.6×10^{-9}		6.5×10^{-8}	8.2×10^{-9}
Carbazole	2.5×10^{-6}	8.4×10^{-8}	3.3×10^{-8}	2.5×10^{-7}		2.9×10^{-6}	3.6×10^{-7}
Chrysene	5.9×10^{-8}	4.1×10^{-9}	7.8×10^{-10}	3.5×10^{-9}		6.7×10^{-8}	8.4×10^{-9}
Dibenzofuran	3.3×10^{-5}	4.1×10^{-7}	4.3×10^{-7}	1.0×10^{-6}		3.5×10^{-5}	1.8×10^{-6}
Fluoranthene	5.9×10^{-7}	2.0×10^{-8}	7.8×10^{-9}	5.9×10^{-8}		6.8×10^{-7}	8.6×10^{-8}
Fluorene	3.8×10^{-6}	4.9×10^{-9}	5.0×10^{-8}	2.3×10^{-8}		3.9×10^{-6}	7.8×10^{-8}
Naphthalene	7.4×10^{-5}	6.2×10^{-7}	9.7×10^{-7}	3.0×10^{-6}		7.9×10^{-5}	4.6×10^{-6}
Phenanthrene	1.6×10^{-6}	4.8×10^{-8}	2.1×10^{-8}	2.1×10^{-7}		1.9×10^{-6}	2.8×10^{-7}
Pyrene	5.1×10^{-7}	1.7×10^{-8}	6.6×10^{-9}	5.0×10^{-8}		5.8×10^{-7}	7.3×10^{-8}

^aFactors in units of lb/ft³ of wood treated. References 11 and 13.

^bDoes not include emissions from preservative return/blowback associated with Boulton process.

TABLE 4-15. SUMMARY OF TEST DATA FOR EMPTY-CELL CHROMATED COPPER ARSENATE WOOD PRESERVING--VACUUM SYSTEM/VACUUM CYCLE^a

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				Range, kg/m ³ (lb/ft ³)	Average, kg/m ³ (lb/ft ³)	
N/K	Chromium	2	D	NA ^b	2.2 x 10 ⁻⁸ (1.4 x 10 ⁻⁹)	10
N/K	Copper	2	D	NA ^b	3.0 x 10 ⁻⁸ (1.9 x 10 ⁻⁹)	10

^aN/K = not known; NA = data not available; kg/m³ = kg of pollutant per cubic meter of wood treated; and lb/ft³ = lb of pollutant per cubic foot of wood treated,

^bOnly the average emission rate for each pollutant was reported in the reference. Therefore, only the average emission factor could be calculated.

TABLE 4-16. SUMMARY OF CANDIDATE EMISSION FACTORS FOR
CREOSOTE EMPTY-CELL WOOD PRESERVING

Process (SCC) ^a	Pollutant	Emission factor, lb/ft ³	Ref. No.
Treatment cycle without conditioning (SCC: 3-07-005-30)	VOC	7.4 x 10 ⁻⁴	11
	Acenaphthene	6.3 x 10 ⁻⁷	13
	Acenaphthylene	1.7 x 10 ⁻⁶	13
	Anthracene	1.6 x 10 ⁻⁸	13
	Benzo(a)anthracene	1.7 x 10 ⁻⁸	13
	Benzo(b)fluoranthene	1.6 x 10 ⁻⁸	13
	Benzo(k)fluoranthene	6.0 x 10 ⁻⁹	13
	Benzo(a)pyrene	8.2 x 10 ⁻⁹	13
	Carbazole	3.6 x 10 ⁻⁷	13
	Chrysene	8.4 x 10 ⁻⁹	13
	Dibenzofuran	1.6 x 10 ⁻⁶	13
	Fluoranthene	8.6 x 10 ⁻⁸	13
	Fluorene	7.8 x 10 ⁻⁸	13
	Naphthalene	4.6 x 10 ⁻⁶	13
	Phenanthrene	2.8 x 10 ⁻⁷	13
	Pyrene	7.3 x 10 ⁻⁸	13
Treatment cycle with conditioning by the Boulton process (SCC: 3-07-005-40)	VOC	5.8 x 10 ⁻³	11
	Acenaphthene	9.9 x 10 ⁻⁶	13
	Acenaphthylene	2.8 x 10 ⁻⁵	13
	Anthracene	1.3 x 10 ⁻⁷	13
	Benzo(a)anthracene	1.3 x 10 ⁻⁷	13
	Benzo(b)fluoranthene	1.3 x 10 ⁻⁷	13
	Benzo(k)fluoranthene	4.8 x 10 ⁻⁸	13
	Benzo(a)pyrene	6.5 x 10 ⁻⁸	13
	Carbazole	2.9 x 10 ⁻⁶	13
	Chrysene	6.7 x 10 ⁻⁸	13
	Dibenzofuran	3.5 x 10 ⁻⁵	13
	Fluoranthene	6.8 x 10 ⁻⁷	13
	Fluorene	3.9 x 10 ⁻⁶	13
	Naphthalene	7.9 x 10 ⁻⁵	13
	Phenanthrene	1.9 x 10 ⁻⁶	13
	Pyrene	5.8 x 10 ⁻⁷	13

^aSCC = Source Classification Code.

TABLE 4-17. CANDIDATE EMISSION FACTORS FOR INORGANIC POLLUTANT EMISSIONS FROM EMPTY-CELL CHROMATED COPPER ARSENATE WOOD PRESERVING^a

Source (SCC)	CASRN	Name	Emission factor		Rating	Ref. No.
			kg/m ³	lb/ft ³		
Vacuum cycle	7440-47-3	Chromium	2.2 x 10 ⁻⁸	1.4 x 10 ⁻⁹	E	10
	7440-50-8	Copper	3.0 x 10 ⁻⁸	1.9 x 10 ⁻⁹	E	10

^a CASRN = Chemical Abstracts Service Registry Number
 kg/m³ = kg of pollutant per cubic meter of wood treated
 lb/ft³ = lb of pollutant per cubic foot of wood treated

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5. DRAFT AP-42 SECTION 10.8

Please refer to AP-42, Section 10.8, Wood Preserving, on the EPA web site.