DEVELOPMENT DOCUMENT
FOR PROPOSED
EFFLUENT LIMITATIONS GUIDELINES,
NEW SOURCE PERFORMANCE STANDARDS,
AND
PRETREATMENT STANDARDS
FOR THE
STEAM ELECTRIC
POINT SOURCE CATEGORY

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SECTION I

CONCLUSIONS

In revising effluent limitations guidelines and standards of performance as well as pretreatment standards for the steam electric power generating industry, separate consideration has been given to heat and to chemical pollutants. In this regulation review, only non-thermal-related pollutants were considered. Another document will address thermal discharges when thermal regulations are proposed.

The analysis of pollutants and the technologies applicable to their control has been based on specific waste streams of concern. These waste streams are primarily a function of fuels used, processes employed, plant site characteristics, and intake water quality. The major waste streams have been defined as direct or indirect products of the treatment system, power cycle system, ash handling system, air pollution control system, coal pile, yard and floor drainage, condenser cooling system and miscellaneous sources. Virtually all steam electric facilities have one or more waste streams associated with these systems and sources.

This review of effluent guidelines focused primarily on the 129 priority pollutants, although other pollutants were also considered. In general, very few of the organics in the list of 129 priority pollutants were detected in quantifiable amounts. Inorganic priority pollutants, however, are found in most waste streams. The review also found that the chlorine (non-conventional pollutants) limitations in the original guidelines were not sufficiently stringent.

Treatment and control technologies currently in use by certain segments of the power industry could be applied to a greater number of powerplants, reducing the discharge of pollutants. The best practicable control technology currently available (BPTCA) will not be changed with exception to provisions relating to boiler blowdown. The best available technology economically achievable (BATEA), new source performance standards (NSPS) and pretreatment standards for new (PSNS) and existing sources (PSES) will be changed to reflect updated information on control technology, waste characterization and other factors.

Although zero discharge of bottom and fly ash handling waters can be achieved by the use of complete recirculating or dry transport systems, the Agency is not requiring zero discharge of bottom and fly ash handling waters for existing facilities. However, zero discharge of fly ash water will be required for new sources. The discharge of priority pollutants as the result of the use of cooling tower maintenance chemicals (which contain the 129 priority pollutants) can be eliminated through proper selection of chemical additives; discharge of chlorine residuals can be also reduced significantly by chemical treatment and implementation of proper chlorine addition procedures.

Pretreatment standards for new and existing sources will require control of discharges resulting from metal cleaning operations, ash transport, and blowdown from cooling tower operations.

EPA has reviewed all powerplant waste streams in this regulation review effort with the exception of ash pile, chemical handling and construction area runoff and discharges from wet scrubbing systems for air pollution control. Regulations for these streams will be proposed when additional data become available. Additional data are also being compiled on bottom and fly ash transport water. Regulations for ash transport streams may be revised upon review of the information.

SECTION II

RECOMMENDATIONS

The effluent limitations guidelines and standards of performance and pretreatment standards for the steam electric power generating point source category are summarized in table II-1. The technologies available to achieve these guidelines are presented in table II-2. These limitations are based on the findings and conclusions presented in this report, and are proposed in compliance with the Federal Water Pollution Control Act Amendments of 1977 (Clean Water Act).

For comparison, the current BPT guidelines are presented in Table II-3.

Table II-1

RECOMMENDED BAT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Proposed BAT: Existing Sources	Proposed Standards of Performance: New Sources	Pretreatment Standards: Existing Sources (1)	Pretreatment Standards: New Sources (1)
All Wastestreams Except Once Through Cooling Water	pH 6-9	pH 6-9	pH not less than 5, unless special case	pH 6-9
All Wastestreams	No Discharge PCB's	No Discharge PCB's	- No pollutants may be introduced to a POTW that shall interfere with operation or performance of that facility - No discharge of PCB's - Copper (total) 1.0 mg/l - Oil and Grease (O&G) 100 mg/l	- No pollutants may be introduced to a POTW that shall interfere with operation or performance of that facility - No discharge PCB's

Table II-1 (Continued)

RECOMMENDED BAT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Proposed BAT: Existing Sources	Proposed Standards of Performance: New Sources	Pretreatment Standards: Existing Sources (1)	Pretreatment Standards: New Sources (1)
Once-Through Cooling Water	Zero discharge of TRC except demonstration of need, then not to exceed 0.14 mg/l and discharge of TRC limited to 2 hours per day per discharge point (unless crustacean control is needed)	Zero discharge of TRC except demonstration of need, then not to exceed 0.14 mg/l and dicharge of TRC limited to 2 hours per day per discharge point (unless crustacean control is needed)	As described under all wastestreams category	As described under all wastestreams category
Cooling Tower Blowdown	TRC not to exceed 0.14 mg/l (max); No discharge of the 129 priority pollutants resulting from chemical additives	TRC not to exceed 0.14 mg/l (max); No discharge of the 129 priority pollutants resulting from chemical additives	No discharge of the 129 priority pollutants resulting from chemical additives.	No discharge of of the 129 priority pollutants resulting from chemical additives

Table II-1 (Continued)

RECOMMENDED BAT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Proposed BAT: Existing Sources	Proposed Standards of Performance: New Sources	Pretreatment Standards: Existing Sources (1)	Pretreatment Standards: New Sources (1)
Bottom Ash Transport Water	Same as BPT	Same as BPT	As described under all wastestreams category	As described under all wastestreams category
Fly Ash Transport Water	Same as BPT	Zero discharge	As described under all wastestreams category	Zero discharge
Metal Cleaning Wastes	Same as BPT	Same as BPT	1 mg/l Cu (max) and as described under all wastestreams category	- Copper (total) 1.0 mg/l
Low Volume Wastes (to include boiler blowdown)	Same as BPT	Same as BPT	As described under all wastestreams category	As described under all wastestreams category

Table II-1 (Continued)

RECOMMENDED BAT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Proposed BAT: Existing Sources	Proposed Standards of Performance: New Sources	Pretreatment Standards: Existing Sources (1)	Pretreatment Standards: New Sources (1)
Ash Pile/ Construction Runoff	Reserve for future consideration	Reserve for future consideration	Reserve for future consideration	Reserve for future consideration
Coal Pile/ Chemical Handling Runoff	Same as BPT	Same as BPT	pH not less than 5; No discharge that would cause process upset	pH 6-9 (except for 10-year, 24-hour rainfall event)
Blowdown for Wet Air Pollution Control Systems (other than for particulate control)	Reserve for future consideration	Reserve for future consideration	Reserve for future consideration	Reserve for future consideration

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NOTE: (1) - All indirect dischargers must comply with the general pretreatment standards (40 CFR 403) in addition to the limitations specified below.

Table II-2

TECHNOLOGIES EVALUATED AS CAPABLE OF ACHIEVING RECOMMENDED LIMITATIONS

Wastestreams	Proposed BAT: Existing Sources	Proposed Standards of Performance: New Sources	Pretreatment Standards: Existing Sources	Pretreatment Standards: New Sources
Once-Through Cooling Water	Chlorine Minimization-Dechlorination	Chlorine Minimization-Dechlorination	No treatment required	No treatment required
Cooling Tower Blowdown	Dechlorination/ Use of alternative chemicals	Dechlorination/Use of alternative chemicals	Use of alternative chemicals	Use of alternative chemicals
Bottom Ash Transport Water	Sedimentation	Sedimentation	Sedimentation	Sedimentation
Fly Ash Transport Water	Sedimentation	Dry transport and disposal	Sedimentation	Dry transport and disposal
Metal Cleaning Wastes	Chemical Precipitation	Chemical Precipitation	Chemical Precipitation	Chemical Precipitation
Low Volume Waste (includes boiler blowdown)	Sedimentation	Sedimentation	Sedimentation	Sedimentation

Table II-2 (Continued)

TECHNOLOGIES EVALUATED AS CAPABLE OF ACHIEVING RECOMMENDED LIMITATIONS

Wastestreams	Proposed BAT: Existing Sources	Proposed Standards of Performance: New Sources	Pretreatment Standards: Existing Sources	Pretreatment Standards: New Sources
Ash Pile/ Construction Runoff	Reserved for future consideration	Reserved for future consideration	Reserved for future consideration	Reserved for future consideration
Coal Pile/ Chemical Handling Runoff	pH adjustment, sedimentation	pH adjustment, sedimentation	pH adjustment, sedimentation	pH adjustment, sedimentation
Blowdown from Wet Air Pollution Control Devices	Reserved for future consideration	Reserved for future consideration	Reserved for future consideration	Reserved for future consideration

Table II-3

EXISTING BPT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Current BPT: Existing Sources	Pretreatment Standards: Existing Sources (2)	Pretreatment Standards: New Sources (2)
All Wastestreams Except Once Through Cooling Water	pH 6-9	pH not less than 5, unless special case	For incompatible pollutants (heavy metals, toxic organics), the pretreatment standards for new sources are identical to BPT
All Wastestreams	No Discharge PCB's	- No pollutants may be introduced to a POTW that shall interfere with operation or performance of that facility - No discharge of PCB's - Copper (total) 1.0 mg/l - Oil and Grease (O&G) 100 mg/l	- No pollutants may be introduced to a POTW that shall interfere with operation or performance of that facility - No discharge of PCBs
Low Volume Wastes	- TSS 100 mg/l (one day max.) 30 mg/l (30 day avg.) - O&G 20 mg/l (one day max.) 15 mg/l (30 day avg.)	As described under all wastestreams category	As described under all wastestreams category

Table II-3 (Continued)

EXISTING BPT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Current BPT: Existing Sources	Pretreatment Standards: Existing Sources (2)	Pretreatment Standards: New Sources (2)
Combined Ash Transport Water	- TSS 100 mg/l (one day max.) 30 mg/l (30 day avg.) - O&G 20 mg/l (one day max.) 15 mg/l (30 day avg.)	As described under all wastestreams category	As described under all wastestreams category
Bottom Ash Transport Water	- TSS 100 mg/l (one day max.) 30 mg/l (30 day max.) - O&G 20 mg/l (one day max.) 15 mg/l (30 day avg.)	As described under all wastestreams category	As described under all wastestreams category
Fly Ash Transport Water	- TSS 100 mg/l (one day max.) 30 mg/l (30 day max.) - O&G 20 mg/l (one day max.) 15 mg/l (30 day max.)	As described under all wastestreams category	No discharge of TSS or O&G (Note: This portion of the fly ash regulation was remanded but is being reproposed as in Table II-1)

Table II-3 (Continued)

EXISTING BPT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Current BPT: Existing Sources	Pretreatment Standards: Existing Sources (2)	Pretreatment Standards: New Sources (2)
Metal Cleaning Wastes	- TSS 100 mg/l (one day max.) 30 mg/l (30 day avg.) - O&G 20 mg/l (one day max.) 15 mg/l (30 day avg.) - Copper (total) 1.0 mg/l (one day max. and 30 day avg.) - Iron (total) 1.0 mg/l (one day max. and 30 day avg.)	As described under all wastestreams category - Copper (total) 1.0 mg/l	As described under all wastestreams category - Copper (total) 1.0 mg/l
Once Through Cooling Water	Free Available Chlorine - 0.5 mg/l (max.) 0.2 mg/l (avg.) and may not be discharged from any one unit more than 2 hours per day and no more than one unit at a time may discharge FAC (unless plant can show reason why more is needed)	As described under all wastestreams category. No chlorine limitation.	As described under all wastestreams category. No chlorine limitation.

Table II-3 (Continued)

EXISTING BPT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Current BPT: Existing Sources	Pretreatment Standards: Existing Sources (2)	Pretreatment Standards: New Sources (2)
Cooling Tower Blowdown	Free Available Chlorine - 0.5 mg/l (max.) 0.2 mg/l (avg.) and may not be discharged from any one unit more than 2 hours per day and no more than one unit at a time may discharge FAC (unless plant can show reason why more is needed)	As described under all wastestreams category. No chlorine limitation.	No discharge of materials added for corrosion inhibition including but not limited to zinc, chromium, phosphorus
Boiler Blowdown	- TSS 100 mg/l (one day max.) 30 mg/l (30 day avg.) - O&G 20 mg/l (one day max.) 15 mg/l (30 day avg.) - Copper (total) 1.0 mg/l (one day max. and 30 day avg.) - Iron (total) 1.0 mg/l (one day max. and 30 day avg.) Note: The new proposed regulations place this stream under the low volume wastes category where only TSS and O&G are regulated.	As described under all wastestreams category. Note: The new proposed regulations place this stream under the low volume wastes category.	Note: The new proposed regulations place this stream under the low volume wastes category where only TSS and O&G are regulated - Copper (total) 1.0 mg/l

Table II-3 (Continued)

EXISTING BPT GUIDELINES AND PRETREATMENT STANDARDS FOR NEW AND EXISTING SOURCES

Wastestreams	Current BPT: Existing Sources	Pretreatment Standards: Existing Sources (2)	Pretreatment Standards: New Sources (2)
Coal Pile/ Chemical Storage Area Runoff	TSS not to exceed 50 mg/l, pH 6-9 (except for 10-year, 24-hour rainfall events)	pH not less than 5, No discharge that would cause process upset	As described under all wastestreams category

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NOTE: (2) - All indirect dischargers must comply with the general pretreatment standards (40 CFR 403) in addition to the limitations specified below.

SECTION III

INTRODUCTION

BACKGROUND

The primary effluent guidelines document for the steam electric power industry (1) was prepared by Burns & Roe and published by the Environmental Protection Agency (EPA) in October 1974. This document still serves as the fundamental source of information for the industry as to its process descriptions, wastewater quantities and compositions, treatment and control technologies, and achievable pollutant levels for conventional and nonconventional pollutants. A supplemental document (2) prepared by Hittman Associates and published by EPA provided information on pretreatment for wastewater discharged by the steam electric industry to publicly owned treatment works (POTW).

Subsequent to the publishing of the Burns & Roe document, three events which have implications for the effluent limitations guidelines for the steam electric power industry have occurred. First, the Settlement Agreement on June 7, 1976 between the Natural Resources Defense Council (NRDC) and EPA (3) requires that EPA develop and promulgate effluent limitations guidelines reflecting best available technology economically achievable (BATEA), standards of performance for new sources, and pretreatment standards for new and existing sources for 21 major industries, taking into account a list of 65 classes of toxic pollutants. This list has now been modified to 129 specific priority pollutants. The original list of 65 classes of pollutants appears in table III-1. The present list of 129 priority pollutants is presented in table III-2. Second, the U.S.Court of Appeals ruling of July 16, 1976 (4) remanded for reconsideration various parts of the October 1974 effluent limitations guidelines for the steam electric industry. Third, the Clean Water Act Amendments of 1977 require the review and, if appropriate, revision of each effluent standard periodically.

PURPOSE OF THIS SUPPLEMENT

This supplemental document provides a basis for the revision of effluent limitations guidelines for the steam electric power industry. It forms the technical basis for the revised steam electric power generating effluent limitations based on the BATEA, new source performance standards (NSPS) and pretreatment standards in conformance with the June 7, 1976 Consent Decree.

The steam electric power industry covered in this document is classified in Standard Industrial Classification (SIC) Codes 4911 and 4931(5). Code 4911 encompasses establishments engaged in the generation, transmission, and/or distribution of electric energy for sale. Code 4931 encompasses establishments primarily engaged in providing electric service in combination with other services, with electric services as the major part though less than 95 percent of the

Table III-1

LIST OF SIXTY-FIVE CLASSES OF POLLUTANTS CONTAINED IN SETTLEMENT AGREEMENT BETWEEN EPA AND NRDC (3)

Acenaphthene
Acrolein
Acrylonitrile
Aldrin/Dieldrin
Antimony and compounds*
Arsenic and compounds
Asbestos
Benzene
Benzidine
Beryllium and compounds
Cadmium and compounds
Carbon tetrachloride
Chlordane (technical mixture and metabolites)
Chlorinated benzenes (other than dichlorobenzenes)
Chlorinated ethanes (included 1,2-dichlorethane, 1,1,1-trichlorethane, and hexachloroethane)
Chloroalkyl ethers (Chloromethyl, chlorethyl, and mixed ethers)
Chlorinated naphthalene
Chlorinated Phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
Chloroform
2-chlorophenol
Chromium and compounds
Copper and compounds
Cyanides
DDT and metabolites
Dichlorobenzenes (1,2-,1,3-, and 1,4-dichlorobenzenes)
Dichlorobenzidene
Dichloroethylenes (1,1-and 1,2-dichloroethylene)
2,4-dichlorophenol
Dichloropropane and dichloropropene
2,4-dimethylphenol
Dinitrotoluene
Diphenylhdrazine
Endosulfan and metabolites
Endrin and metabolites
Ethylbenzene
Fluoranthene
Haloethers (other than those listed elsewhere; includes chlorophenylphenyl ethers, bromophenylphenyl ether, bis (dischloroisopropyl) ether, bis-(chloroethoxy) methane and polychlorinated diphenyly ethers)

Table III-1 (Continued)

LIST OF SIXTY-FIVE CLASSES OF POLLUTANTS CONTAINED IN SETTLEMENT AGREEMENT BETWEEN EPA AND NRDC (3)

Halomethanes (other than those listed elsewhere; includes
  methylene chloride methylchloride, methylbromide, bromoform,
  dichlorobromomethane, trichlororfluoromethane,
  dichlorodifluoromethane)
Heptachlor and metabolites
Hexachlorobutadiene
Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentadiene
Isophorone
Lead and compounds
Mercury and compounds
Naphthalene
Nickel and compounds
Nitrobenzene
Nitrophenols (Including 2,4-dinitrophenol, dinitrocresol)
Nitrosamines
Pentachlorophenol
Phenol
Phthalate esters
Polychlorinated biphenyls (PBCs)
Polynuclear aromatic hydrocarbons (Including benzanthracenes,
  benzopyrenes, benzofluoranthene, chrysense,
  dibenzanthracenes, and indenopyrenes)
Selenium and compounds
Silver and compounds
2,3,7,8,-Tetrachlorodibenzo-p-dioxin (TCDD)
Tetrachloroethylene
Thallium and compounds
Toluene
Toxaphene
Trichloroethylene
Vinyl chloride
Zinc and compounds

*As used throughout this table the term "compounds" shall include organic and inorganic compounds.

Table III-2

LIST OF 129 PRIORITY POLLUTANTS (2)

Compound Name

1. *acenaphthene (B)***
2. *acrolein (V)***
3. *acrylonitrile (V)
4. *benzene (V)
5. *benzidene (B)
6. *carbon tetrachloride (tetrachloromethane) (V)

*Chlorinated benzenes (other than dichlorobenzenes)

7. chlorobenzene (V)
8. 1,2,4-trichlorobenzene (B)
9. hexachlorobenzene (B)

*Chlorinated ethanes (including 1,2-dichloroethane, 1,1,1-trichloroethane and hexachloroethane)

10. 1,2-dichloroethane (V)
11. 1,1,1-trichlorethane (V)
12. hexachlorethane (B)
13. 1,1-dichloroethane (V)
14. 1,1,2-trichloroethane (V)
15. 1,1,2,2-tetrachloroethane (V)
16. chloroethane (V)

*Chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)

17. bis (chloromethyl) ether (B)
18. bis (2-chloroethyly) ether (B)
19. 2-chloroethyl vinyl ether (mixed) (V)

*Chlorinated naphtalene

20. 2-chloronaphthalene (B)

*Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)

21. 2,4,6-trichlorophenol (A)***
22. parachlorometa cresol (A)
23. *chloroform (trichloromethane) (V)
24. *2-chlorophenol (A)

Table III-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS (2)

*Dichlorobenzenes

25. 1,2-dichlorobenzene (B)
26. 1,3-dichlorobenzene (B)
27. 1,4-dichlorobenzene (B)

*Dichlorobenzidine

28. 3,3'-dichlorobenzidine (B)

*Dichloroethylenes (1,1-dichloroethylene and 1,2-dichloroethylene)

29. 1,1-dichloroethylene (V)
30. 1,2-trans-dischloroethylene (V)
31. *2,4-dichlorophenol (A)

*Dichloropropane and dichloropropene

32. 1,2-dichloropropane (V)
33. 1,2-dichloropropylene (1,3-dichloropropene) (V)
34. *2,4-dimenthylphenol (A)

*Dinitrotoluene

35. 2,4-dinitrotoluene (B)
36. 2,6,-dinitrotoluene (B)
37. *1,2-diphenylhydrazine (B)
38. *ethylbenzene (V)
39. *fluoranthene (B)

*Haloethers (other than those listed elsewhere)

40. 4-chlorophenyl phenyl ether (B)
41. 4-bromophnyl phenyl ether (B)
42. bis(2-chloroisopropyl) ether (B)
43. bis(2-chloroethoxy) methane (B)

*Halomethanes (other than those listed elsewhere)

44. methylene chloride (dichloromethane) (V)
45. methyl chloride (chloromethane) (V)
46. methyl bromide (bromomethane) (V)
47. bromoform (tribromomethane) (V)
48. dichlorobromomethane (V)

Table III-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS (2)

49. trichlorofluoromethane (V)
50. dichlorodifluoromethane (V)
51. chlorodibromomethane (V)
52. *hexachlorobutadiene (B)
53. *hexachlorocyclopentadiene (B)
54. *isophorone (B)
55. *naphthalene (B)
56. *nitrobenzene (B)

*Nitrophenols (including 2,4-dinitrophenol and dinitrocesol)

57. 2-nitrophenol (A)
58. 4-nitrophenol (A)
59. *2,4-dinitrophenol (A)
60. 4,6-dinitro-o-cresol (A)

*Nitrosamines

61. N-nitrosodimethylamine (B)
62. N-nitrosodiphenylamine (B)
63. N-nitrosodi-n-propylamine (B)
64. *pentachlorophenol (A)
65. *phenol (A)

*Phthalate esters

66. bis(2-3ethylhexyl) phthalate (B)
67. butyl benzyl phthalate (B)
68. di-n-butyl phtalate (B)
69. di-n-octyl phtalate (B)
70. diethyl phtalate (B)
71. dimethyl phthalate (B)

*Polynuclear aromatic hydrocarbons

72. benzo (a)anthracene (1,2-benzanthracene) (B)
73. benzo (a)pyrene (3,4-benzopyrene) (B)
74. 3,4-benzofluoranthene (B)
75. benzo(k)fluoranthane (11,12-benzofluoranthene) (B)
76. chrysene (B)
77. acenaphthylene (B)
78. anthracene (B)
79. benzo(ghi)perylene (1,12-benzoperylene) (B)
80. fluroene (B)
81. phenathrene (B)

Table III-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS (2)

82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene) (B)
83. indeno (1,2,3-cd)(2,3,-o-phenylenepyrene) (B)
84. pyrene (B)
85. *tetrachloroethylene (V)
86. *toluene (V)
87. *trichloroethylene (V)
88. *vinyl chloride (chloroethylene) (V)

Pesticides and Metabolites

89. *aldrin (P)
90. *dieldrin (P)
91. *chlordane (technical mixture and metabolites) (P)

*DDT and metabolites

92. 4,4'-DDT (P)
93. 4,4'-DDE(p,p'DDX) (P)
94. 4,4'-DDD(p,p'TDE) 9 (P)

*endosulfan and metabolites

95. a-endosulfan-Alpha (P)
96. b-endosulfan-Beta (P)
97. endosulfan sulfate (P)

*endrin and metabolites

98. endrin (P)
99. endrin aldehyde (P)

*heptachlor and metabolites

100. heptachlor (P)
101. heptachlor epoxide (P)

*hexachlorocyclohexane (all isomers)

102. a-BHC-Alpha (P) (B)
103. b-BHC-Beta (P) (V)
104. r-BHC (lindane)-Gamma (P)
105. g-BHC-Delta (P)

Table III-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS (2)

*polychlorinated biphenyls (PCB's)

106. PCB-1242 (Arochlor 1242) (P)
107. PCB-1254 (Arochlor 1254) (P)
108. PCB-1221 (Arochlor 1221) (P)
109. PCB-1232 (Arochlor 1232) (P)
110. PCB-1248 (Arochlor 1248) (P)
111. PCB-1260 (Arochlor 1260) (P)
112. PCB-1016 (Arochlor 1016) (P)
113. *Toxaphene (P)
114. *Antimony (Total) (P)
115. *Arsenic (Total)
116. *Asbestos (Fibrous)
117. *Beryllium (Total)
118. *Cadmium (Total)
119. *Chromium (Total)
120. *Copper (Total)
121. *Cyanide (Total)
122. *Lead (Total)
123. *Mercury (Total)
124. *Nickel (Total)
125. *Selenium (Total)
126. *Silver (Total)
127. *Thallium (Total)
128. *Zinc (Total)
129. **2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

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*Specific compounds and chemical classes as listed in the consent degree.

**This compound was specifically listed in the consent degree. Because of the extreme toxicity (TCDD), EPA recommends that laboratories not acquire analytical standard for the compound.

***B = analyzed in the base-neutral extraction fraction
V = analyzed in the volatile organic fraction
A = analyzed in the acid extraction fraction
P = pesticide

total. The SIC Manual (5) recommends that, when available, the value of receipts or revenues be used in assigning industry codes for transportation, communication, electric, gas, and sanitary services. This study was limited to powerplants comprising the steam electric utility industry and did not include steam electric powerplants in industrial, commercial or other facilities. Electric generating facilities other than steam electric, such as combustion gas turbines, diesel engines, etc., are included to the extent that power generated by the establishment in question is produced primarily through steam electric processes. This report covers effluents from both fossil-fueled and nuclear plants, but excludes the radiological aspects of effluents.

The Clean Water Act (6) requires EPA to consider several factors in developing effluent limitation guidelines and standards of performance for a given industry. These include the total cost of applying a technology in relation to the effluent reduction benefits realized; the age of equipment and facilities; the processes employed; the engineering aspects of applying various types of control techniques; process changes; nonwater quality environmental impacts (including energy requirements); and other factors. For steam electric powerplants, a formal subdivision of the industry on the basis of the factors mentioned in the Act was inapplicable. The two basic aspects of the effluents produced by the industry--chemical and thermal--involve such divergent considerations that a basic distinction between guidelines for chemical wastes and thermal discharges was determined to be most useful in achieving the objectives of the Act. Accordingly, this report covers waste categorization, control and treatment technology, and recommendations for effluent limitations for chemical and other non-thermal aspects of waste discharge.

INFORMATION AVAILABILITY, SOURCES AND COLLECTION

Since the publication of the Burns & Roe document in 1974, EPA has collected additional information on the industry profile, its waste characteristics, and applicable treatment technologies. In addition, the NRDC settlement agreement focused attention on the need for information concerning pollutants in the wastewaters. As a result of this attention, there have been various studies on the priority pollutants as to their occurrence in wastewater from the steam electric power industry.

The data base for effluent limitations and standards for the steam electric industry was revised on the basis of the following information sources:

1. A profile of the Steam Electric Power Generating point source category which lists the name of each plant; its location, age, and size; its wastewater characteristics; and its pollutant control technologies.

2. Available data from published and unpublished literature; demonstration project reports; the steam electric industry; manu-

facturers and suppliers of equipment and chemicals used by the industry; various EPA, federal, state, and local agencies; and responses to EPA's 308 letter (1976).

3. Engineering plant visits.

5. Result of sampling program at selected plants.

The current effluent guidelines are divided into four subcategories: generating units, small units, old units, and area runoff. Economic considerations, rather than chemical discharge characteristics, were the determining criteria for differentiating the first three subcategories. Available information indicates that the types of pollutants discharged by powerplants do not differ significantly among plants of varying age and size; the chemical waste characteristics are similar for similar waste sources. Limitations within each subcategory were therefore specified for each of the in-plant waste sources. These included: (1) cooling water; (2) ash-bearing streams; (3) metal cleaning waste; (4) low volume waste; (5) area runoff; and (6) wet flue gas cleaning blowdown.

Section 308 Data Forms

In order to carry out the Settlement Agreement with NRDC, EPA collected additional information on the production processes, raw waste loads, treatment methods, and effluent quality associated with the steam electric industry. This information was obtained via a data collection effort pursuant to Section 308 of the Clean Water Act (6). Section 308 letters and data collection questionnaires were sent to approximately 900 powerplants in the United States of which a total of 812 responded. The data in the responses were coded and subsequently keypunched onto data cards and loaded into a computerized data base. The data base was instrumental in supporting selection of plants for the sampling visits, as well as a valuable tool in establishing how many plants employ what technologies relevant to pollution generation or control.

Data Gathering and Analysis

Initial historical data gathering consisted of visiting the 10 EPA regional offices and several state environmental departments, contacting other EPA offices and governmental agencies, and conducting an extensive literature search. The initial phase of the data gathering effort occurred during the latter part of 1976 and early part of 1977. This was followed by the tabulation of each set of data corresponding to an outfall of a particular plant in terms of pollutant parameters monitored against the date of analysis. This information consisted of the list of the various streams being discharged through this particular outfall and the control or treatment technology to which these streams are subjected.

Screen Sampling Program

A screen sampling program was developed to determine the presence of the 129 priority pollutants in steam electric power industry effluents. EPA selected eight plants for the screen sampling. These plants had indicated in their 308 responses that their discharge was known to contain one or more of the 129 priority pollutants. Selection was also based upon various plant variables which could affect plant discharge and effluent composition. The eight plants selected for the screen sampling program were Plants 4222, 2414, 0631, 1720, 3404, 2512, 3805, and 4836.

The screen sampling procedures followed the Environmental Protection Agency Screen Sampling Procedure for the Measurement of Priority Pollutants (7). Grab and continuous composite samples were collected over 24-hour sampling periods. The continuous 24-hour samples were collected by automatic samplers and maintained at 4 C, while the grab samples were maintained at ambient temperature levels which did not exceed 4 C. At the end of the 24-hour sampling period, samples were preserved according to protocol.

Representatives of both EPA and the electric power industry were present during all sampling. Parallel sampling (two separate samples) and analysis were conducted. Samples of all waste streams were analyzed by both EPA-contracted laboratories and power industry-contracted laboratories.

The EPA-contracted analytical laboratory used analytical procedures derived from Standard Methods for the Examination of Water. Organics were analyzed by first extracting the sample into base, neutral, acid, and volatile fractions and then analyzing each fraction by gas chromatography with a mass spectrometer detector (GC/MS). Cyanide was analyzed by steam distillation followed by the standard colorimetric method. Samples were analyzed for heavy metals by atomic adsorption spectrophotometry.

Although the screen sampling program was intended only to determine the presence or absence of the 129 priority pollutants, the methods of analysis did yield numerical concentrations for detected compounds. Thus, the screening data provided quantified values for detected priority pollutants.

Verification Sampling Program

A verification program followed screen sampling in order to quantify further the pollutant loadings from the power generating industry. This sampling program was used to verify the results of the screen sampling program for both organic and inorganic analyses. Verification involved more plants and was a more intensive effort compared to the screening study. The sixteen plants selected for the verification sampling program were Plants 2718, 1716, 3414, 4826, 1742, 1245, 1226, 4251, 3404, 4602, 3920, 3924, 3001, 1741, 5410, and 2121.

Representatives of both EPA and the electric power industry were present during all the verification sampling. Splits of a single collected sample were used; one half of the original sample went to the EPA-contracted analytical laboratory and the other half went to the power industry-contracted laboratory.

Two additional plants were added to the verification data base as data became available from another contractor using the methods and format of the sixteen earlier verification studies. These are Plants 5409 and 5604.

Sampling and preservation procedures were similar to those of the screen sampling program, except that identical, not parallel, samples were collected for shipment to the EPA and power industry analytical laboratories.

In total, samples from eighteen plants were analyzed by several different EPA-contracted laboratories. Analytical procedures included gas chromatography (GC) or gas chromatography-mass spectrometry (GC/MS) for the organics, and spark source mass spectrometry (SSMS) or atomic absorption (AA) for most of the inorganics. Mercury was analyzed by cold-vapor atomic adsorption. Selenium was analyzed by fluorometry and cyanide by a colorimetric procedure.

Surveillance and Analysis Sampling Program

Additional data were provided through several EPA regional Surveillance and Analysis (S&A) programs conducted by those regions. S&A programs involve periodic visits to powerplants by EPA sampling teams to collect data to determine if the plants are complying with NPDES permits. During some of these visits arrangements were made for the sampling of priority pollutants. Eight plants are represented in this data base; they are Plants 1002, 1003, 4203, 2608, 2603, 2607, 2750, and 5513.

The sampling, preservation, and analytical procedures used by S&A were similar to those employed in both the screening study and the verification study. Analytical methods included gas chromatography mass spectrometry (GC/MS) for organics or ICAP for inorganics.

Waste Characterization Data Base

After evaluation of all the data from the three sampling efforts--screening, verification, and S&A sampling--the Agency decided that all three sets of data were useful in establishing the presence and quantifying the concentration of priority pollutants in discharges from steam electric powerplants. All three sets of data were stored in computerized files such that they could be analyzed as a single data base representing 34 plants.

Engineering Visits to Steam Electric Plants

Eight steam electric plants were visited from March to April 1977 to obtain information on specific plant practices and to develop a sampling and analysis program to verify collected data, to fill existing gaps, and to provide additional information. Specific information gathered included data on raw waste loads, water use, treatment technology, fuel handling systems, and general plant descriptions. Additional engineering visits were conducted from August through September 1979. These visits were to collect data and water samples from plants with recycling bottom ash sluice systems. Fly ash handling methods also were evaluated during these visits.

INDUSTRY DESCRIPTION

Steam electric powerplants produce electric power. The industry also transmits and distributes electric energy. The industry is made up of two basic ownership categories--investor owned and publicly owned -- with the latter further divied into Federal agencies, non-Federal agencies, and cooperatives. About two-thirds of the 3,400 systems in the United States perform only the distribution function, but many perform all three functions: production (generally referred to as generation), transmission, and distribution. In general, the larger systems are vertically integrated, while the smaller systems, largely in the municipal and cooperative categories, rely on purchases to meet all or part of their requirements. Many of the systems are interconnected and can, under emergency conditions, obtain power from other systems.

The industry started around 1880 with the construction of Edison's steam electric plant in New York City. For the next 60 years, growth was continuous but unspectacular due to the fairly limited demand for power; since 1940, however, the annual per capita production of electric energy has grown at a rate of about 6 percent per year and the total energy consumption by about 7 percent (1). As of 1978, there were over 2,600 generating plants in the United States. These systems had a combined generating capacity of 573,800 megawatts (MW) and produced 2,295 billion kilowatt hours (MWh) of energy (8). Table III-3 shows the number of plants, capacity, and annual generation of the total electric utility industry as well as the steam electric sector. Non steam electric generation sources include principally hydroelectric, diesel, and combustion gas turbines. Table III-4 shows the number of plants and their capacity for various size categories.

The addition of new plants will alter the 1978 plant and capacity distribution. By 1985, EPA projects that there will be an additional 161,100 megawatts of capacity added by new plants in the steam electric sector. In the period 1986-1990, the addition of 81,300 megawatts is expected. These projections were derived from Temple, Barker and Sloane, Inc. (TBS) projections of future capacity requirements (8). Table III-5 shows the present and future capacity of the industry.

Table III-3

DISTRIBUTION OF THE STEAM SECTION RELATIVE TO THE ENTIRE ELECTRIC UTILITY INDUSTRY AS OF 1978* (8, 9)

	Capacity (gigawatts)	Generation (billion kilowatt hours)	Number of Plants
Total Industry	573.8	2,295	>2,600
Steam Sector	453.3	1,951	842
Percent of Total Industry Included in Steam Sector	79%	85%	<32%

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*The number and capacity of plants in each category is based on the 1979 DOE _Inventory of Powerplants_ data base. Plants listed in the DOE _Inventory_ as having a net dependable capacity of zero were excluded.

Table III-4

YEAR-END 1978 DISTRIBUTION OF STEAM ELECTRIC PLANTS BY SIZE CATEGORY* (8, 9)

	0-25 MW	26-100 MW	101-200 MW	201-350 MW	351-500 MW	Over 500 MW	Total
Total MW in Category	1,273	9,466	16,777	24,125	33,282	368,342	453,265
Percent of Total MW in Category	0.3%	2.1%	4.0%	5.3%	7.0%	81.3%	100.0%
Number of Plants in Category	98	172	115	87	79	291	842
Percent of Total Plants in Category	11.6%	20.4%	13.7%	10.3%	9.4%	34.6%	100.0%

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*The number and capacity of plants in each category is based on the 1979 DOE Inventory of Powerplants data base. Plants listed in the DOE Inventory as having a net dependable capacity of zero were excluded.

Table III-5

PRESENT AND FUTURE CAPACITY OF THE ELECTRIC UTILITY INDUSTRY (8, 9)

(capacity in gigawatts at year end)

	1978	1985	1990	1995
Generating Capacity				
Total Industry	573.8	750.3	834.9	1003.8
Steam Sector	453.3	614.4	695.7	855.4

Source: DOE *Inventory of Powerplants* (1979) and projections made by Temple, Barker and Sloane, Inc.

The U.S. Department of Energy provided information on the number and capacity of existing steam electric powerplants by size category and fuel type (9). The fuel mix of future plants was determined from the fuel types of the announced plant additions, adjusted to account for some expected fuel shifts, especially from oil or gas to coal (8). This infromation is presented in tables III-6 and III-7. A summary of existing and projected total capacity versus fuel type is presented in table III-8.

Steam electric powerplants discharge waste heat with once-through cooling systems, recirculating cooling systems, or a combination of both. The type of cooling system is important in determining the values of a plant's effluent discharge and therefore the cost of treating the discharge. Plants with once-through cooling water systems discharge the cooling water after only one or two passes through the plant. The waste heat is dissipated to a receiving body of water. Plants with recirculating cooling water systems in most cases use cooling towers, either forced draft or natural draft, and recirculate the water through the plant. A blowdown stream is typically discharged from a recirculating system to control the buildup of dissolved solids. The cooling mechanism, evaporation, results in the discharge of waste heat to the atmosphere and evaporation of water concentrates dissolved solids. Of the existing plants approximately 65 percent or 547 plants use once through cooling and 35 percent or 295 plants use recirculating cooling water systems.

The distribution of plants by age and size category appears in table III-9. Plants built since 1971 represent about 40 percent of steam electric capacity. Plants built before 1961 represent only about 26 precent of the existing capacity.

PROCESS DESCRIPTION

The "production" of electrical energy always involves the conversion of some other form of energy. The three most important sources of energy which are converted to electric energy are the gravitational potential energy of water, the atomic energy of nuclear fuels, and the chemical energy of fossil fuels. The use of water power involves the transformation of one form of mechanical energy into another prior to conversion to electrical energy and can be accomplished at greater than 90 percent of theoretical efficiency. Therefore, hydroelectric power generation produces only a minimal amount of waste heat through conversion inefficiencies. Current uses of fossil fuels, on the other hand, are based on a combustion process, followed by steam generation to convert the heat first into mechanical energy and then to convert the mechanical energy into electrical energy. Nuclear processes in general also depend on the conversion of thermal energy (heat) to mechanical energy via a steam cycle (1).

Hydroelectric Power

Hydroelectric power uses the energy of falling water to produce electric power. Although the facility construction and development

Table III-6

NUMBER OF EXISTING STEAM-ELECTRIC POWERPLANTS BY FUEL TYPE AND SIZE (8, 9)

(number of plants)

	Plant Size Categories						
Fuel Type	0-25 MW	26-100 MW	101-200 MW	201-350 MW	351-500 MW	More Than 500 MW	Total
Existing (1979)							
Coal	35	63	36	38	35	145	352
Oil/Gas	48	102	76	48	44	111	429
Nuclear	0	2	2	0	0	34	38
Other	15	5	1	1	0	1	23
Total	98	172	115	87	79	291	842

Source: DOE Inventory of Powerplants (1979).

Table III-7

CAPACITY OF EXISTING AND NEW STEAM-ELECTRIC POWERPLANTS BY FUEL TYPE AND SIZE (8, 9)
1978-1995
(gigawatts)

	Plant Size Categories						
Fuel Type	0-25 MW	26-100 MW	101-200 MW	201-350 MW	351-500 MW	More Than 500 MW	Total
Existing (1979)							
Coal	.46	3.46	5.59	10.47	14.77	192.61	227.37
Oil/Gas	.67	5.69	10.71	13.33	18.52	121.16	170.07
Nuclear	0	.16	.35	0	0	53.31	53.83
Other	.14	.16	.13	.32	0	1.25	2.10
Total	1.27	9.47	16.78	24.12	33.29	368.33	453.37
Additions (1978-1985)							
Coal							79.20
Oil/Gas							19.80
Nuclear							85.40
Total							184.40
Additions (1986-1995)							
Coal							187.30
Oil/Gas							.20
Nuclear							142.10
Total							329.60
Total Additions (1978-1995)							514.00

Source: DOE *Inventory of Powerplants*.

Table III-8

EXISTING AND PROJECTED DISTRIBUTION OF STEAM ELECTRIC POWERPLANTS BY FUEL TYPE (8, 9)

(capacity in gigawatts)

	1978[a]	1985[b]	1990[b]	1995[b]
Coal Capacity	227.4	301.8	365.1	473.9
Number of Plants	352	467	565	734
Oil/Gas Capacity	170.1	173.5	157.4	100.4
Number of Plants	429	438	397	253
Nuclear Capacity	53.8	139.0	173.1	281.0
Number of Plants	38	98	122	198

Sources:

[a] DOE, Inventory of Powerplants, (1979).

[b] Electrical World; September 15, 1979; and projections by Temple, Barker, and Sloane, Inc.

Table III-9

DISTRIBUTION OF STEAM-ELECTRIC CAPACITY BY PLANT SIZE AND IN-SERVICE YEAR (9)

Plant Age Category	Plant Size Category 0-25	26-100	101-200	201-350	351-500	>500	Total	Percent of Total Capacity
Pre-1960 MW	1,154	6,656	12,926	17,362	16,749	64,968	119,815	
Percent of Age Category	1	5.6	10.8	14.5	14	54	100	26
1961-1970 MW	344	2,157	4,052	6,570	9,630	112,844	135,597	
Percent of Age Category	.3	1.6	3.0	4.8	7.1	83	100	30
Post-1970 MW	20	1,135	1,543	3,942	7,539	184,502	198,681	
Percent of Age Category	.01	.6	.8	2	3.8	93	100	44
Total MW	1,518	9,948	18,521	27,874	33,918	362,314	454,093	
Percent of Age Category	.3	2	4	6	7	80	100	100

Source: DOE *Inventory of Powerplants*, 1979.

costs are high, the fuel itself is not an operational cost. Unfortunately, the availability of hydroelectric power is limited to locations where nature has created the opportunity of providing both water and elevation differences to make the energy extractable. The total hydroelectric capacity installed at the end of 1975 amounted to about 5 percent of the total installed United States generating capacity. This share of power is projected to decline to less than 0.1 percent by 1983 (8), primarily because the number of sites available for development have already been developed and the remaining sites are either too costly or too far from urban centers (10).

Another form of hydroelectric power is produced by means of pumped storage projects. The process involves pumping water into an elevated reservoir during off-peak load hours, and then generating electricity at peak load periods by conventional hydroelectric means. Although not as efficient as once-through hydroelectric power facilities, pumped storage projects are favorable for the peak load periods when power demands are very high and additional power generation capacity is needed to supplement the normal load generators.

In general, hydroelectric power represents a viable alternative to fossil-fueled or nuclear steam cycle generation where geographic, environmental, and economic conditions are favorable (1).

Steam Electric Powerplants

Steam electric powerplants are the production facilities of the electric power industry. The process to produce electricity can be divided into four stages. In the first operation, fossil fuel (coal, oil, or natural gas) is burned in a boiler furnace. The evolving heat is used to produce pressurized and superheated steam. This steam is conveyed to the second stage--the turbine-- where it gives energy to rotating blades and, in the process, loses pressure and increases in volume. The rotating blades of the turbine act to drive an electric generator or alternator to convert the imparted mechanical energy into electrical energy. The steam leaving the turbine enters the third stage--the condenser--where it is condensed to water. The liberated heat is transferred to a cooling medium which is normally water. Finally, the condensed steam is reintroduced into the boiler by a pump to complete the cycle.

Historically, powerplants were categorized in accordance with the type of fuel they burned. Recently, however, because of the energy crisis and other cost factors, powerplants have modified their equipment to enable them to use more than one fuel. Based on 308 data, 78 percent of the steam electric powerplants have the capability of using two or more fossil fuels, which indicates that the majority of all steam electric plants have the capability to burn more than one type of fossil fuel.

Figure III-1 shows a simplified flow diagram of a typical coal-fired powerplant. The figure depicts features which are common to all

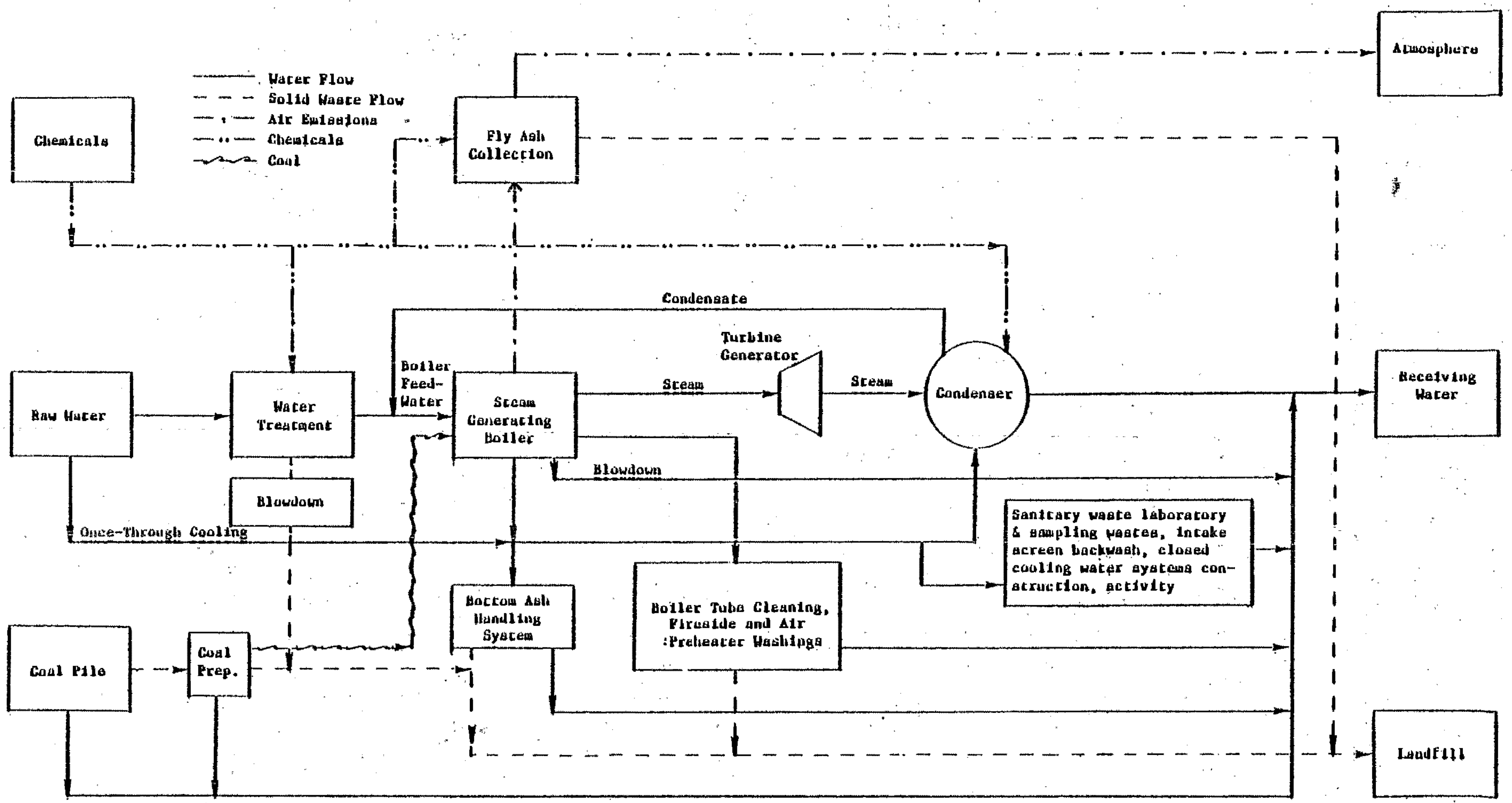
Water Flow
Solid Waste Flow
Air Emissions
Chemicals
Coal
Chemicals
Fly Ash Collection
Atmosphere
Condensate
Turbine Generator
Raw Water
Water Treatment
Boiler Feed-Water
Steam Generating Boiler
Steam
Steam
Condenser
Receiving Water
Blowdown
Blowdown
Once-Through Cooling
Sanitary waste laboratory & sampling wastes, intake screen backwash, closed cooling water systems construction, activity
Coal Pile
Coal Prep.
Bottom Ash Handling System
Boiler Tube Cleaning, Fireside and Air Preheater Washings
Landfill

Figure III-1

TYPICAL COAL-FIRED STEAM ELECTRIC PLANT

powerplants as well as features which are unique to coal-fired facilities. Features unique to coal-fired plants include coal storage and preparation (transport, beneficiation, pulverization, drying), coal-fired boiler, ash handling and disposal system, and flue gas cleaning and desulfurization. A brief description of these features and their environmental results is presented in subsequent sections of this document. EPA anticipates that future designs will emphasize recovery and reuse of resources, in particular recycle of water and use of fly ash as a resource.

Combustion Gas Turbines and Diesel Engines

Combustion gas turbines and diesel engines are devices for converting the chemical energy of fuels into mechanical energy by using the Brayton and Diesel thermal cycles as opposed to the Rankine cycle used with steam. In a combustion gas turbine, fuel is injected into compressed air in a combustion chamber. The fuel ignites, generating heat and combustion gases, and the gas mixture expands to drive a turbine, which is usually located on the same axle as the compressor. Various heat recovery and staged compression and combustion schemes are in use to increase overall efficiency. Aircraft jet engines have been used to drive turbines which, in turn, are connected to electric generators. In such units, the entire jet engine may be removed for maintenance and a spare installed with a minimum of outage time. Combustion gas turbines require little or no cooling water and therefore produce no significant effluent. Diesel engines, which can be operated at partial or full loads, are capable of being started in a very short time, so they are ideally suited for peaking use. Many large steam electric plants contain diesel generators for emergency shutdown and startup power (1). In 1975, gas turbine and diesel-powered electric generation plants represented 6.8 percent of the total United States generating capacity. By 1983 the number of gas turbine and diesel-powered electrical generation plants is projected to decline to less than 0.1 percent of the total United States electric generating capacity (2).

Nuclear Powerplants

Nuclear powerplants utilize a cycle similar to that used in fossil-fueled powerplants except that the source of heat is atomic interactions rather than combustion of fossil fuel. Water services as both moderator and coolant as it passes through the nuclear reactor core. In a pressurized water reactor, the heated water then passes through a separate heat exchanger where steam is produced on the secondary side. This steam, which contains no radioactive materials, drives the turbines. In a boiling water reactor, steam is generated directly in the reactor core and is then piped directly to the turbine. This arrangement produces some radioactivity in the steam and therefore requires some shielding of the turbine and condenser. Long term fuel performance and thermal efficiencies are similar for the two types of nuclear systems (1).

Alternative Processes Under Active Development

Future Nuclear Types

At the present time almost all of the nuclear powerplants in operation in the United States are of the boiling water reactor (BWR) or pressurized water reactor (PWR) type. Some technical aspects of these types of reactors limit their thermal efficiency to about 30 percent. There are potential problems in the area of fuel availability if the entire future nuclear capacity is to be met with these types of reactors. In order to overcome these problems, a number of other types of nuclear reactors are in various stages of development. The objective of developing these reactors is two fold: to improve overall efficiency by being able to produce steam under temperature and pressure conditions similar to those being achieved in fossil fuel plants and to assure an adequate supply of nuclear fuel at a minimum cost. Included in this group are the high temperature, gas-cooled reactor (HTGR), the seed blanket light water breeder reactor (LWBR), the liquid-metal fast breeder reactor (LMFBR), and the gas-cooled fast breeder reactor (GCFBR). All of these utilize a steam cycle as the last stage before generation of electric energy. Both the HTGR and the LMFBR have advanced sufficiently to be considered as potentially viable alternate processes.

The HTGR is a graphite-moderated reactor which uses helium as a primary coolant. The helium is heated to about 750 degrees Centigrade (1,400 degrees Fahrenheit) and then gives up its heat to a steam cycle which operates at a maximum temperature of about 550 degrees centigrade (1,000 degrees Fahrenheit). As a result, the HTGR can be expected to produce electric energy at an overall thermal efficiency of about 40 percent. The thermal effects of its discharges should be similar to those of an equivalent capacity fossil-fueled plant. Its chemical wastes will be provided with essentially similar treatment systems which are presently being provided for BWR and PWR plants.

The LMFBR will have a primary and secondary loop cooled with sodium and a tertiary power producing loop utilizing a conventional steam system. Present estimates are that the LMFBR will operate at an overall thermal efficiency of about 36 percent, although higher efficiencies are deemed to be ultimately possible. The circulating water thermal discharges of the LMFBR will initially be about halfway between those of the best fossil-fueled plants and the current generation of nuclear plants. Chemical wastes will be similar to those of current nuclear plants (1).

Coal Gasification

Coal gasification involves the production of fuel gas by the reaction of the carbon in the coal with steam and oxygen. The processes of this energy technology are divided into two groups depending upon the heating value of the product gas. Low Btu gasification utilizes air as the oxygen source and produces a CO and H_2 rich gas with a heating value of 150 - 450 Btu/scf. High Btu gasification utilizes pure oxygen in the gasification process and produces a fuel gas of pipeline quality with a heating value of approximately 1,000 Btu/scf. The main difference between high and low Btu processing is the inclusion of shift conversion and methanation processes in the processing sequence for high Btu gasification.

The Federal Government and a number of private organizations are supporting research and development of coal gasification complexes. Estimates indicate that low Btu gasification of coal can be accomplished for less than twice the current natural gas price paid by electric utilities. As natural gas and fuel oil become increasingly short in supply, gasification of coal could well turn into a factor in steam electric power generation.

Combined Cycle Powerplants

Combined cycle power systems combine gas turbine and steam turbine cycles to increase thermal efficiencies of power generation. The hot exhaust gases from a gas turbine are used to generate steam in an unfired boiler. The steam generated is used to drive a conventional steam turbine. Combined cycle systems might consist of a number of gas turbines exhausted into a single steam turbine with its own electric generating capacity. Another combined cycle concept is a pressurized bed system. The concept is to burn coal in a fluidized bed environment of dolomite at 10 atmospheres of pressure. Steam is produced in the conventional manner of using boiler heat for the steam cycle but cleaned combustion gases are also used to produce electricity by use of a gas turbine. Waste heat is used to economize the cycle through preheating of boiler feed water.

FUTURE GENERATING SYSTEMS

Natural Energy Sources

Geothermal Energy. Geothermal energy is the natural heat contained in the crust of the earth. While ubiquitous throughout the earth's crust, only in a few geological formations is it sufficiently concentrated and near enough to the surface to make its recovery economically viable. Geothermal energy involves six major resource types of which two are currently capable of being utilized for the generation of electricity. Vapor-dominated reservoirs, such as those utilized at The Geysers, California, obtain steam directly from wells drilled into the geothermal reservoirs. The steam is then used to drive a steam turbine. Liquid-dominated reservoirs contain geothermal fluids consisting of hot water and steam. The geothermal fluids must first be flashed to steam or used to evaporate some other types of working fluid, which is then used to drive a steam turbine.

The advantage of geothermal power generation is that the energy source is essentially free after the initial exploration, drilling, and facility costs are paid off. The disadvantages of geothermal power generation are that the costs of facility siting and construction are *high, and geothermal* fluids must be cleaned prior to use and disposed of by reinjection to the subsurface geothermal reservoir.

Solar Energy. The conversion of solar energy to electricity at a large scale via a steam cycle involves the use of a large array of reflective focusing collectors which concentrate the solar radiation on a heat collector which heats water to steam. The steam is used to drive a steam turbine to produce electricity. The systems currently in use are developmental, and it is projected that, in the future, as fossil fuels become increasingly short in supply and high in cost, solar systems will be developed in areas which are geographically suited to maximum solar collection and conversion.

Biomass Conversion. This involves the production of photosynthetic materials (wood, sugar cane, and other similar high Btu content crops) for use as a fuel. The photosynthetic materials can be directly combusted in coal-fed type boilers or converted into low Btu gas by gasification of the biomass. The technology behind biomass production and utilization closely resembles agricultural techniques and techniques evolved from the handling of coal. As a result, the utilization of biomass materials as a heat source for steam electric generation will increase as demands are placed on the coal industry to provide cleaner fuel at low prices.

Other Natural Energy Sources. Other major energy conversion processes (ocean thermal gradiant to electricity, wind energy to electricity, photovoltaics, and solar heating and cooling of buildings and water) involve mechanical conversion or the transfer of heat without the production of steam for use as a working fluid.

Magnetohydrodynamics

Magnetohydrodynamics (MHD) power generation consists of passing a hot ionized gas or liquid metal through a magnetic field to generate direct current. The concept has been known for many years, although specific research directed towards the development of viable systems for generating significant quantities of electric energy has only been in progress for the past 10 years. Magnetohydrodynamics have particular potential as a "topping" unit used in conjunction with a conventional steam turbine. Exhaust from a MHD generator is hot enough to be utilized in a waste heat boiler resulting in an overall system efficiency of 50 to 60 percent. The problem associated with MHD is the development of materials which can withstand the temperature generated. Despite its high efficiency, development of MHD to a commercial operation is not expected to occur within the next several years in the United States (1).

Electrogasdynamics

Electrogasdynamics (EGD) produces power by passing an electrically charged gas through an electric field. The process converts the kinetic energy of the moving gas to high voltage direct current electricity. The promise of EGD is similar to the promise of MHD.

Units would be smaller, would have a minimum of moving parts, would not be limited by thermal cycle efficiencies, and would not require cooling water. The system could also be adapted to any source of fuel or energy including coal, gas, oil or nuclear reactors. Unfortunately, the problems of developing commercially practical units are also similar to those associated with MHD (1).

Fuel Cells

Fuel cells are electrochemical devices, similar to storage batteries, in which the chemical energy of a fuel such as hydrogen is converted continuously into low voltage electric current. The prospect of fuel cells is for use in residential and commercial services. However, the fuel cell is not expected to replace a significant portion of the central powerplant generator facilities within the next several years due to expense of manufacturing and the significant quantity of electric power needed to produce the cells.

SECTION IV

INDUSTRY CATEGORIZATION

The 1974 Development Document (1) presented the framework and rationale for the recommended industry categorization which was subsequently used in the development of chemical-type waste effluent limitations under best practicable control technology, best available technology economically achievable, and standards of performance for new sources. Factors which were considered in the development of the industry categorization included analysis of the processes employed; raw materials used; the number and size of generating facilities; their age, and site characteristics; mode of operation; wastewater characteristics; pollutant parameters; control and treatment technology; and cost, energy and non-water quality aspects. As a result, it was recommended that the industry be categorized according to the origin of individual waste sources, including: condenser cooling system; water treatment; boiler or PWR steam generator; maintenance cleaning; ash handling; drainage; air pollution control devices; and miscellaneous waste streams.

Since the issuance of the 1974 Development Document (1), additional information has been collected through questionnaire surveys, plant visits, and sampling and analysis programs for priority pollutants. The steam electric power generating point source category has been reevaluated in light of this new information to determine whether categorization and subcategorization would be required for the preparation of effluent guidelines and standards for the industry. The reevaluation consisted of: (1) the statistical analysis of 308 questionnaire data to assess the influence of age, size (installed generating capacity), fuel type, and geographic location on wastewater flow; and (2) engineering technical analysis to assess the influence of these and other variables on wastewater pollutant loading and the need for subcategorization.

On the basis of the reevaluation studies, EPA concluded that the existing categorization approach (by chemical waste stream origin) was adequate, but that a new format would be an improvement. The recommended categorization for the steam electric power generating point source category includes:

1. Once-Through Cooling Water

2. Recirculating Cooling System Blowdown

3. Fly Ash Transport Discharge

4. Bottom Ash Transport Discharge

5. Metal Cleaning Wastes

    - Air preheater wash
    - Fireside wash

- Boiler tube cleaning
- Cleaning rinses

6. Low Volume Wastes

   - Clarifier blowdown
   - Makeup water filter backwash
   - Lime softener blowdown
   - Ion exchange softener regeneration
   - Demineralizer regeneration
   - Powdered resin demineralizer back flush
   - Reverse osmosis brine
   - Boiler blowdown
   - Evaporator blowdown
   - Laboratory drains
   - Floor drains
   - Sanitary wastes
   - Diesel engine cooling system discharge

7. Ash Pile, Chemical Handling and Construction Area Runoff

8. Coal Pile

9. Wet Flue Gas Cleaning Blowdown

The following subsections of this section describe the statistical analysis and engineering technical analysis performed as a part of the categorization reevaluation.

STATISTICAL ANALYSIS

Flow data from the steam electric 308 questionnaire data base were obtained for once-through cooling water, recirculating cooling system blowdown, ash transport discharge, and low volume waste discharges. Flow values were normalized by installed plant generating capacity and expressed in gallons per day per megawatt.

Four independent variables were studied to determine their effect on waste flow discharge. They were: principal fuel type (oil, coal, gas); EPA region; generating capacity; and age. The effect of these four variables on normalized waste flow discharge was tested using analysis of covariance. Results of the analysis indicated those independent variables which have a statistically significant effect on waste flow discharge and therefore warranted further consideration as a basis for subcategorization. Table IV-1 presents the independent variables which were found statistically to have an influence on normalized waste flow discharges. In general, fuel type was found to have the greatest influence on normalized discharge flow. This was expected because water requirements for ash transport and other uses normally vary among oil, coal, and gas-fired plants.

Although some statistically significant influences were found, their practical significance requires further examination. Table IV-2 lists

Table IV-1

VARIABLES FOUND TO HAVE A STATISTICALLY SIGNIFICANT INFLUENCE ON NORMALIZED FLOW DISCHARGES

	Independent Variable			
Normalized Discharge Source	Fuel Type	Capacity	EPA Region	Age
Once Through Cooling Water		x		
Recirculating Cooling Water Blowdown	x			
Ash Transport Discharge	x			
Low Volume Waste Discharge	x		x	

Table IV-2

PERCENT OF THE VARIATION IN NORMALIZED DISCHARGE FLOWS THAT IS EXPLAINED BY THE INDEPENDENT VARIABLES

Discharge Source	Percent of the Variation in Normalized Discharge Explained by the Independent Variables
Once Through Cooling	9.6
Recirculating Cooling Water Blowdown	16.5
Ash Transport Discharge	18.6
Low Volume Waste Discharge	18.3

the percent of the variation in normalized flow discharge which is explained by the four independent variables investigated. In statistical terminology, these percentages are the square of the multiple correlation coefficient (R^2), expressed as a percent. The relatively low R^2 values indicate that although some of the independent variables were shown to statistically influence discharge, their importance is largely overshadowed by other influences. Less than 20 percent of the variation in normalized ash transport discharge was explained by the influences of fuel type, plant capacity, EPA region and plant age. The Agency therefore concluded that there was no strong statistical basis for establishing discharge source subcategories by fuel type, plant capacity, EPA region, or plant age.

ENGINEERING TECHNICAL ANALYSIS

The objective in developing any system of industry subcategorization is to provide logical groupings of discharges based on those factors which affect the waste loading from the plant. The effect on the waste loading must be of sufficient magnitude to warrant imposition of a different treatment technology or to affect radically the performance of an existing technology.

The following characteristics of steam electric power generating plants were considered in establishing the basis for industry subcategorization:

1. Age
2. Size (Installed Generating Capacity)
3. Fuel Type
4. Intake Water Quality
5. Geography
6. Source of Raw Waste

These factors were selected as having the greatest potential effect on powerplant waste loading.

Age

Previous analyses (1) have shown that older plants (defined by the year the oldest currently operating boiler was placed in service) tend to be smaller, tend to have urbanized locations, and are somewhat more likely to discharge plant wastewaters to publicly owned treatment works (POTW's). Of these factors only the size of the facilities is likely to impact wastewater quality or loading. Smaller plants do have smaller discharges compared to large plants but the quality of the discharge is not appreciably different.

The biggest influence of plant age is on the economics of power generation. Older plants are less efficient than new ones and the cost of producing electricity is generally higher. It is therefore logical that capital investment in, as well as operating expenses of, pollution control equipment in older facilities can cause more economic hardship as compared to newer more efficient facilities. The economic issues are addressed in the economic evaluation being prepared as a companion document to this one.

The influence of age was judged not to be of a nature to warrant future subcategorization beyond the division by wastewstreams as presented earlier.

Size

As noted above station size (commonly expressed as installed generating capacity in megawatts) is an important factor influencing the volume of effluent flow. Discharge flows of cooling water, boiler feed water, ash handling water, and other waste streams all increase with increasing installed capacity. In general, small stations produce about the same quality of wastewater as compared to larger stations.

Fuel Type

The type of fuel (coal, oil, gas, nuclear) used to fire powerplant boilers most directly influences the number of powerplant waste streams. The influence comes principally from the effect of fuel on the ash transport waste stream. Stations using heavy or residual oils such as no. 6 fuel oil generate fly ash in large quantities and may generate some bottom ash. This ash must be handled either dry or wet. Wet handling produces a waste stream. Stations which use wet removal methods have an ash sluice water stream that typically contains heavy metals including priority pollutants. Stations which burn coal create both fly ash and bottom ash. As in the case of oil ash, both types of coal ash can be removed either by wet or by dry methods. Those power stations using wet ash removal methods have an ash sluice water stream containing inorganic toxic pollutants such as arsenic, selenium, copper, etc.

Since fuel can affect both the presence and concentration of pollutants, fuel type does have a strong influence on waste loading and could serve as a potential basis for subcategorization. The existing categorization by waste stream source, however, does include the effect of fuel type by establishing limitations for ash transport water and further subcategorization of those waste streams by fuel type is not necessary.

Intake Water Quality

Quality of the intake water has both a direct and an indirect effect on the waste loading and discharge flow of a power station. The direct effect is that pollutants coming into the plant tend to be eventually discharged by the plant. The indirect effects are more complex. High concentrations of dissolved solids in the intake water can require more frequent regeneration of boiler water treatment systems. High dissolved solids content may also limit the amount of recycle of cooling water from the cooling towers, thus increasing the flow of cooling tower blowdown. High organic loadings in the raw water intake require larger doses of chlorine or other chemicals for cooling water treatment. Water quality is normally divided into three types: fresh, brackish, and salt, depending on the concentration of dissolved solids. The different types of water are believed to react differently with chlorine and other biocidal agents to produce different types and different concentrations of reaction products.

Intake water quality can affect both the flow and pollutant concentration in water discharges. However, its influence on cooling water flows is mostly dependent on the type of cooling used by the station. The influence of intake water quality is accounted for in the present categorization and was rejected as a basis for subcategorization.

Geographic Location

Geographic location can have an influence on power station waste concentrations and flows primarily through the affect of intake water availability and quality. The effect of intake water quality is described above. Other geographical oriented considerations have small to no effect on wastewater flow or quality.

Waste Stream Source

Steam electric powerplant waste stream source has the strongest influence on the presence and concentration of various pollutants as well as on flow. Waste stream source effects all aspects of waste loading. Power stations commonly have several wastewater sources, but rarely are all possible sources present at any single station. All of the sources present fit into one of the general categories. Categorization by waste source provides the best mechanism for evaluating and controlling waste loads. It was concluded that current categorization by waste stream source should be retained.

SECTION V

WASTE CHARACTERIZATION

INTRODUCTION

This study addresses only the chemical aspects of powerplant wastewater discharge. A number of different operations by steam electric powerplants discharge chemical wastes. Many wastes are discharged more or less continuously as long as the plant is operating. These include wastewaters from the following sources: cooling water systems, ash handling systems, wet-scrubber air pollution control systems, and boiler blowdown. Some wastes are produced at regular intervals, as in water treatment operations which include a cleaning or regenerative step as part of their cycle (ion exchange, filtration, clarification, evaporation). Other wastes are also produced intermittently but are generally associated with either the shutdown or startup of a boiler or generating unit such as during boiler cleaning (water side), boiler cleaning (fire side), air preheater cleaning, cooling tower basin cleaning, and cleaning of miscellaneous small equipment. Additional wastes exist which are essentially unrelated to production. These depend on meteorological or other factors. Rainfall runoff, for example, causes drainage from coal piles, ash piles, floor and yard drains, and from construction activity. A diagram indicating potential sources of wastewaters containing chemical pollutants in a fossil fueled steam electric powerplant is shown in figure V-1.

DATA COLLECTION

Data on waste stream characteristics presented in this section were accumulated from the following sources:

1. The 1974 Development document for the Steam Electric Industry (1);

2. Literature data available since 1974 supplied by various sources, including the steam electric industry;

3. Individual plant information available from approximately 800 steam electric plants responding to an EPA data collection effort (under authority of section 308 of the FWPCA);

4. Data from monthly monitoring reporting forms, EPA regional offices, state agencies, and other Federal agencies;

5. Results of screen sampling and analysis of steam electric facilities;

6. Results of verification sampling and analysis of steam electric facilities; and

7. Miscellaneous data sources.

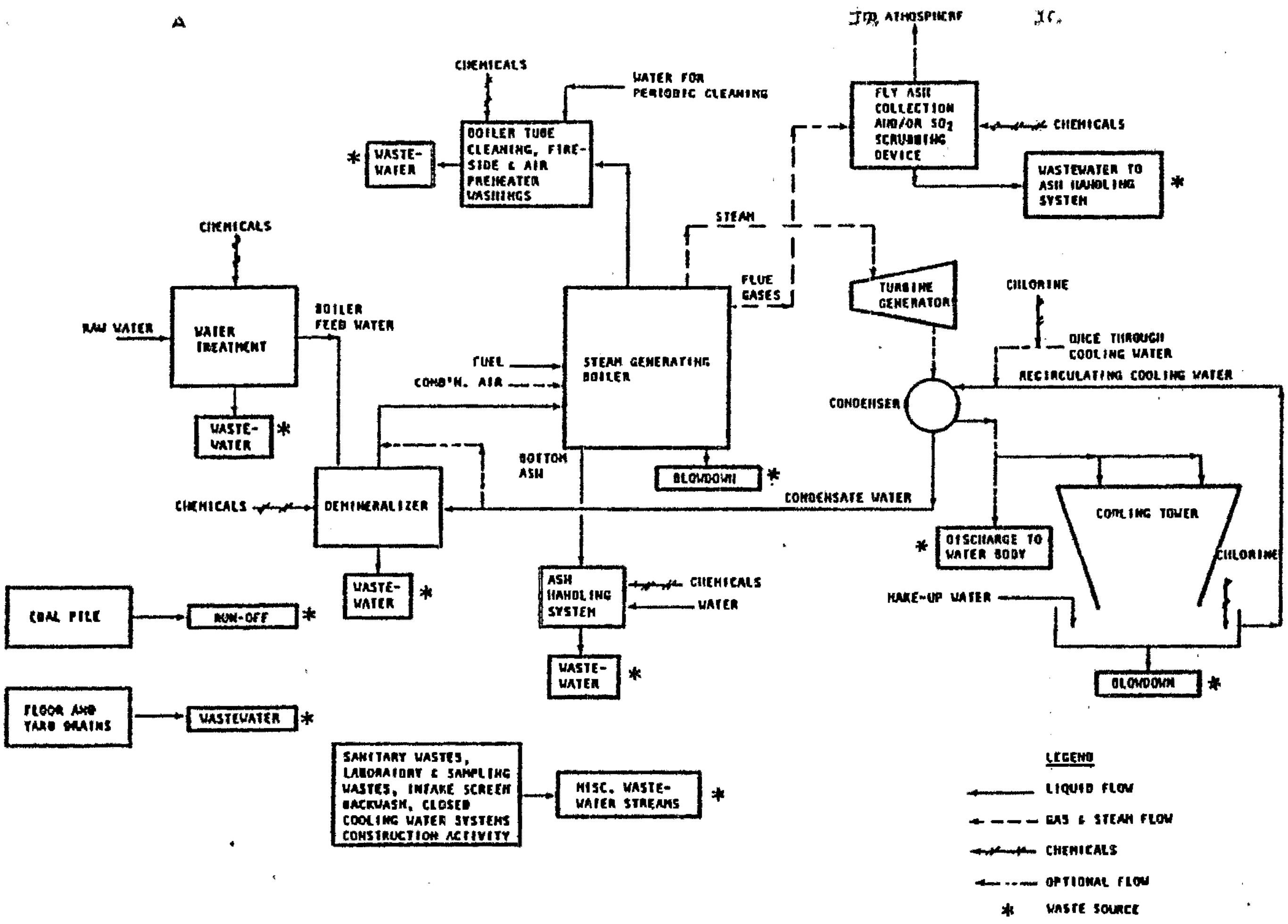
TO ATMOSPHERE
CHEMICALS
WATER FOR PERIODIC CLEANING
WASTE-WATER
BOILER TUBE CLEANING, FIRE-SIDE & AIR PREHEATER WASHINGS
FLY ASH COLLECTION AND/OR SO2 SCRUBBING DEVICE
CHEMICALS
WASTEWATER TO ASH HANDLING SYSTEM
STEAM
CHEMICALS
FLUE GASES
TURBINE GENERATOR
CHLORINE
RAW WATER
WATER TREATMENT
BOILER FEED WATER
FUEL
COMB'N. AIR
STEAM GENERATING BOILER
ONCE THROUGH COOLING WATER
RECIRCULATING COOLING WATER
CONDENSER
WASTE-WATER
BOTTOM ASH
BLOWDOWN
CHEMICALS
DEMINERALIZER
CONDENSATE WATER
COOLING TOWER
DISCHARGE TO WATER BODY
CHLORINE
ASH HANDLING SYSTEM
CHEMICALS
WATER
MAKE-UP WATER
COAL PILE
RUN-OFF
WASTE-WATER
WASTE-WATER
BLOWDOWN
FLOOR AND YARD DRAINS
WASTEWATER
SANITARY WASTES, LABORATORY & SAMPLING WASTES, INTAKE SCREEN BACKWASH, CLOSED COOLING WATER SYSTEMS CONSTRUCTION ACTIVITY
MISC. WASTE-WATER STREAMS
LEGEND
LIQUID FLOW
GAS & STEAM FLOW
CHEMICALS
OPTIONAL FLOW
* WASTE SOURCE

Figure V-1

SOURCES OF WASTEWATER IN A FOSSIL-FUELED STEAM ELECTRIC POWER PLANT (1)

Most of the historical data available cover conventional and non-conventional non-toxic pollutants such as total residual chlorine, free available chlorine, temperature, non-priority metals, oil and grease, total suspended solids (TSS), and pH. Data covering the organic priority pollutants were practically nonexistent. A two fold sampling program was conducted to fill the data void. The initial "screening" phase served to identify the presence of pollutants and the "verification" phase to quantify them. Five analytical laboratories were involved in the sampling program. All the laboratories used gas chromotography with a mass spectrometer detector (GC/MS) in analyzing for the organics (with one exception) and atomic adsorption for the metals (with two exceptions). One laboratory used a GC with a Hall detector for organic analyses. Two laboratories used the Inductively Coupled Argon Plasma Atomic-Emission Spectroscopy Method (ICAP) for metal analyses. The sampling protocol outlined in the document entitled, "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants--April 1977 (2), was used with some minor revisions. The revisions are described in the subsections on each waste stream.

Methylene chloride and phthalates were detected in almost all samples. The potential sources of contamination for these pollutants include sampling and analytical equipment (phthalates are used as plasticizer in tubing) and reagent used to clean and prepare sample bottles (methylene chloride). For these reasons, phthalates and methylene chloride are excluded from consideration as pollutants from powerplant operation.

Screen Sampling Efforts

Eight plants were chosen for example under the screen sampling phase. These plants were representative of the pollutant sources encountered in the industry; the selection of plants was based on plant variables known to affect effluent composition. The selection criteria included: fuel type, plant size, cooling type, and feed water quality. The characteristics of these eight plants are summarized in table V-1.

Verification Sampling Efforts

The verification sampling phase was developed to quantify pollutant loadings from the power-generating industry. Plants were chosen for this phase after consultation with industry representatives and computer scans of the 308 data base. The rationale for plant selection was based on chemical discharge waste characteristics. This phase focused primarily on the following streams: once-through cooling water, cooling tower blowdown, and ash handling waters. Although this sampling effort emphasized these major waste sources, other waste streams were also sampled.

Pollutants discharged from once-through cooling water can be attributed to corrosion of construction materials, and to the reaction of elemental chlorine as hydrochlorite with organics in the intake

Table V-1

CHARACTERISTICS OF PLANTS SAMPLED IN THE SCREEN SAMPLING PHASE OF THE SAMPLING PROGRAM

Plant	Capacity (MW)	Fuel Type	Fly Ash Collection	Fly Ash Handling	Cooling Water System/ Type of Water
4222	1641.7	Bituminous Coal	ESP	Once-Through Sluicing	Cooling Towers/Fresh Water
0631	169	Oil/Gas	Cyclones	Dry Handling	Cooling Towers/Fresh Water
2414	1329	Bituminous Coal	Units 1, 2: ESP Unit 3: Scrubber	Units 1, 2: Dry Handling Unit 3: Partial Recirculation Sluice System	Units 1,2: Once-Through/Fresh Water Unit 3: Cooling Tower/Fresh Water
1720	1107	Bituminous Coal	-----	Once-Through Sluicing	Once-Through/Fresh Water
3805	660	Lignite Coal	-----	Partical Recirculating Sluice System	Once-Through/Saline Water
3404	475.6	Coal/Oil	ESP	Reinjection of Fly Ash Into Boilers	Units 1, 2: Cooling Towers/Saline Water Unit 3: Once-Through /Saline Water
2512	1120	Oil	ESP	Partial Recirculation of Fly Ash Sluice	Once-Through/Saline Water
4836	495	Gas	-----	-----	Cooling Towers/Fresh Water

water. Primary emphasis for cooling waters was placed on organics. Plants sampled during the verification program were selected on the basis of intake water quality. Powerplants with fresh water intake, brackish water intake, and saline water intake were selected because reaction kinetics for chlorinated organics formation are known to differ with the nature of the water source.

Pollutants in cooling tower blowdown may be the result of chlorination, chemical additives, and corrosion and erosion of the piping, condenser, and cooling tower materials. The Agency therefore, considered materials of construction (in particular cooling tower fills) in plant selection. Plants using the three most prevalent types of cooling tower fill were sampled. Plants with fresh, brackish, and saline water intakes were selected for chlorinated organics sampling. Since most of the powerplants were chlorinating on an intermittent basis, cooling tower and once-through cooling effluents were sampled only during periods of chlorination.

Ash handling streams contain dissolved material from the ash particles. The chemical nature of the ash material is a function of fuel composition. The four basic fuels considered were: coal, oil, natural gas, and nuclear. Natural gas-fired and nuclear-fired plants do not generate ash. Responses from the 308 letters indicate that few oil-fired plants have wet ash-sluicing systems. Only one plant with oil ash handling waters was sampled. As a result, the ash transport waters from coal-fired powerplants were the primary focus. Four factors were determined to have the greatest impact on this stream: (1) sulfur content; (2) type of coal (bituminous, lignite, etc.); (3) origin of coal; and (4) type of boiler. Plants were selected under these criteria. Most coal-fired facilities have ash ponds or other means of treatment for total suspended solid removal. Samples were taken from the ash pond effluent. Table V-2 lists the powerplants sampled during the verification phase of the sampling program. Information regarding plant fuel type, installed generating capacity, ash handling systems, and cooling system type are provided in this table.

Sampling Program Results

The results of the screening and verification sampling programs are discussed by specific waste stream in the following subsections:

1. Cooling Water
    - once-through
    - recirculating
2. Ash Handling
    - combined ash ponds
    - separate fly ash and bottom ash ponds
3. Boiler Blowdown

Table V-2

CHARACTERISTICS OF PLANTS SAMPLED IN THE VERIFICATION PHASE

Plant No.	Capacity MW	Fuel Type	Fly Ash Handling System	Bottom Ash Handling System	Cooling Water System/ (Fill*)/Type of Water
2718	136.9	Lignite Coal	Dry	Dry	Once-Through and Cooling Tower (Wood)/ Fresh
1716	648.5	Bituminous Coal/Gas	Dry	Wet Once-Through	Once-Through/Fresh
3414	612.9	Oil	-----	-----	Once-Through/Brackish
4826	826.3	Gas	N/A	N/A	Once-Through/Brackish
1742	22	Bituminous Coal/Oil	Dry	Wet Once-Through	Once-Through/Fresh
1245	117	Oil/Gas	-----	-----	Once-Through/Brackish Cooling Tower/Fresh
1226	1,229	Bituminous Coal/Oil/Gas	Wet Once-Through	Wet Once-Through	Once-Through and Cooling Tower (PVC)/ Fresh
4251	835	-----	-----	-----	Cooling Tower (Asbestos)/Fresh

NA = Not Applicable
---- = Insufficient Information
*Type of Fill in Cooling Towers; given where appropriate.

Table V-2 (Continued)

CHARACTERISTICS OF PLANTS SAMPLED IN THE VERIFICATION PHASE

Plant No.	Capacity MW	Fuel Type	Fly Ash Handling System	Bottom Ash Handling System	Cooling Water System/ Type of Water
3404	475.6	Bituminous Coal/Oil	Wet Once-Through	Wet Once-Through	Once-Through and Cooling Tower (Asbestos)/Brackish
5409	2,900	Bituminous Coal/Oil	Wet Once-Through	Wet Once-Through	Cooling Tower (----)/ Fresh
5604	750	Bituminous Coal/Oil	Dry/Wet Recycle	Wet Once-Through/ Wet Recycle	Once-Through and Cooling Tower (----)/ Fresh
4602	22	Subbituminous Coal	Dry	Wet Once-Through	Cooling Tower (Wood)/ Fresh
3920	544	Bituminous Coal/Oil	Wet Once-Through	Dry/Wet Once-Through	Once-Through/----
3924	87.5	Bituminous Coal	Wet Once-Through	Wet Once-Through	Once-Through/----
3001	50.0	Lignite Coal/Gas	Wet Once-Through and Wet Recycle	Wet Once-Through	Once Through/----

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NA = Not Applicable
---- = Insufficient Information
*Type of Fill in Cooling Towers; given where appropriate.

Table V-2 (Continued)

CHARACTERISTICS OF PLANTS SAMPLED IN THE VERIFICATION PHASE

Plant No.	Capacity MW	Fuel Type	Fly Ash Handling System	Bottom Ash Handling System	Cooling Water System/ Type of Water
1741	99.0	Bituminous Coal	Wet Once-Through	Wet Once-Through	Cooling Ponds/----
5410	675	Bituminous Coal	Wet Once-Through	Wet Once-Through	Once-Through/----
2121	1,002.6	Bituminous Coal	Wet Once-Through	Wet Recycle (Bottom Ash Sluice Water Recycled for Fly Ash Sluicing)	Cooling Tower (----)/ ----

---

NA = Not Applicable
---- = Insufficient Information
*Type of Fill in Cooling Towers; given where appropriate.

4. Metal Cleaning Wastes

5. Boiler Fireside Washing

6. Air Preheater Washing

7. Coal Pile Runoff

A listing of the pollutants detected in the various powerplant waste streams is given in table V-3.

COOLING WATER

In a steam electric powerplant, cooling water absorbs the heat that is liberated from the steam when it is condensed to water in the condensers. A typical type of condenser for steam electric power applications is the shell and tube condenser. A crosssectional view of this type of condenser is provided in figure V-2. Cooling water enters the condenser through the inlet box and passes through the condenser tubes to the outlet box. As the water passes through the tubes, heat is transferred across the tube walls to the cooling water from steam contained in the condenser shell. The steam in the shell is the turbine exhaust. The transfer of heat to the cooling water results in condensation of steam on the condenser tubes. The condensate falls from the tubes to the bottom of the shell forming a pool in the hot well. The condensate is then pumped from the hot well through the feedwater train to the boiler. Cooling water is discharged from the condenser through the outlet box (3).

Once-Through Cooling Water Systems

In a once-through cooling water system, the cooling water is withdrawn from the water source, passed through the system, and returned directly to the water source. The components of the system are the intake structure, the circulating water pumps, the condensers, and the discharge conduit. The components of a typical intake structure are the intake cowl, the conduit, and the wet well. Each intake cowl contains a bar rack to remove large objects from the water in order to protect the pumps. The wet well contains the pumps, called the circulating water pumps, and screens for removing smaller objects in the water which could damage the pumps. The relative location of the components in a particular application depends on the type of water source and various physical characteristics of the water source. The discharge from the recirculating water pumps enter a manifold that distributes the cooling water to the condensers. A manifold collects the heated water from all of the condensers and transfers the water to a conduit. The cooling water is discharged from the conduit into the receiving water body. Based on 308 data, approximately 65 percent of the existing steam electric powerplants have once-through cooling water systems. Table V-4 presents a statistical analysis of once-through cooling water flow rates reported in 308 responses from the industry.

Table V-3

SUMMARY TABLE OF ALL PRIORITY POLLUTANTS DETECTED IN ANY OF THE WASTE STREAMS FROM STEAM ELECTRIC POWERPLANTS BASED ON THE ANALYSIS OF THE COMPLETE COMPUTERIZED DATA BASE

Benzene
Chlorobenzene
1,2-Dichloroethane
1,1,1-Trichloroethane
1,1,2-Trichloroethane
2-Chloronaphthalene
Chloroform
2-Chlorophenol
1,2-Dichlorobenzene
1,4-Dichlorobenzene
1,1-Dichloroethylene
1,2-Trans-Dichloroethylene
2,4-Dichlorophenol
Ethylbenzene
Methylene Chloride
Bromoform
Dichlorobromomethane
Trichlorofluoromethane
Chlorodibromomethane
Nitrobenzene
Pentachlorophenol
Phenol
Bis(2-Ethylhexyl) Phthalate
Butyl Benzyl Phthalate
Di-N-Butyl Phthalate
Di-N-Octyl Phthalate
Diethyl Phthalate
Dimethyl Phthalate
Tetrachloroethylene
Toluene
Trichloroethylene
4,4-DDD
Antimony (Total)
Arsenic (Total)
Asbestos (Total-Fibers/Liter)
Beryllium (Total)
Cadmium (Total)
Chromium (Total)
Copper (Total)
Cyanide (Total)
Lead (Total)
Mercury (Total)
Nickel (Total)
Selenium (Total)
Silver (Total)
Thallium (Total)
Zinc (Total)

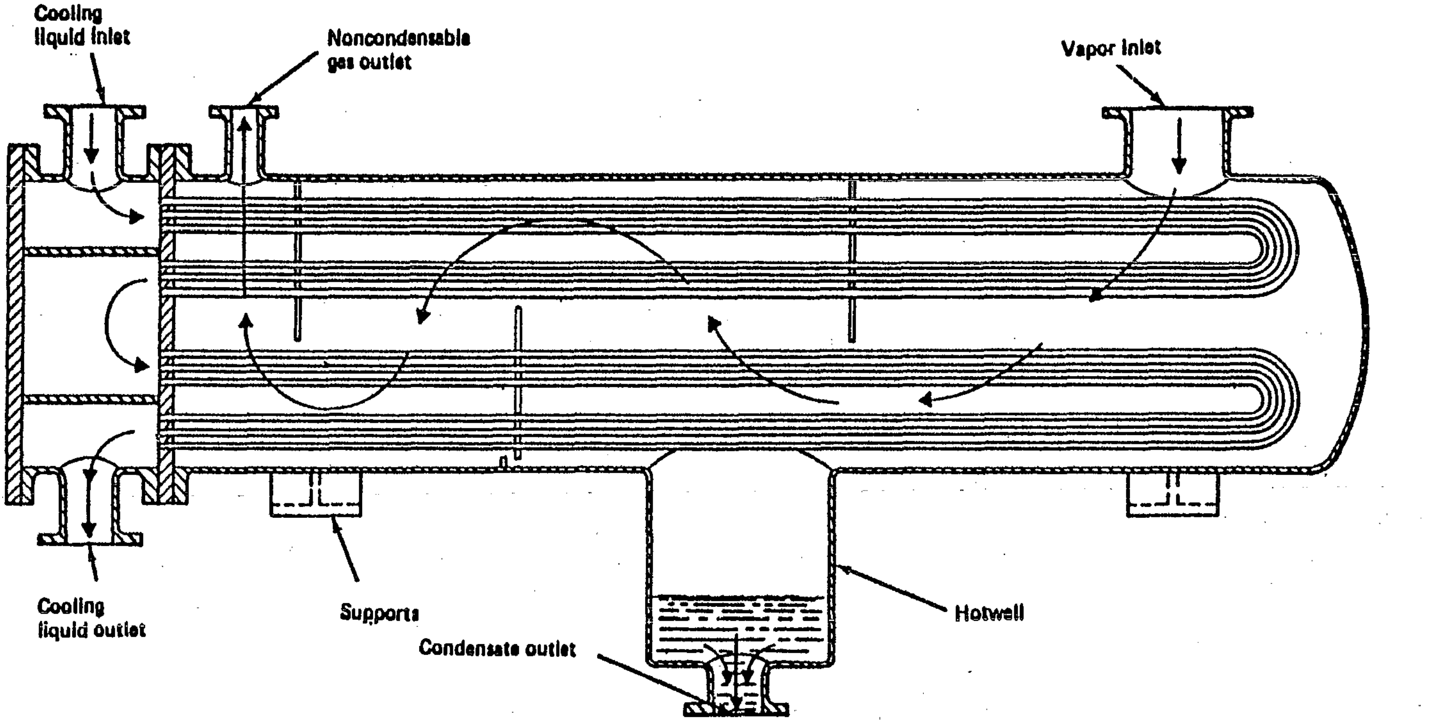
Cooling liquid inlet
Noncondensable gas outlet
Vapor inlet
Cooling liquid outlet
Supports
Condensate outlet
Hotwell

Figure V-2

SHELL AND TUBE CONDENSER

Reprinted from Handbook of Chlorination by G. C. White by permission of Van Nostrand Reinhold Company. Year of first publication: 1972.

Table V-4

ONCE-THROUGH COOLING WATER FLOWRATES
(308 Questionnaire)

Variable	Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: Coal*					
Flow: GPD/plant	239	298,048,949	358,035,167.6	50.0	1,662,900,000
Flow: GPD/MW	239	1,140,619,218	5,030,338,485	0.347	55,430,000
Fuel: Gas*					
Flow: GPD/plant	105	206,671,665.8	539,322,309.7	79.2	1,905,000,000
Flow: GPD/MW	104	636,267,895	573,486.38	1.8	3,658,536,585
Fuel: Oil*					
Flow: GPD/plant	138	393,313,121.5	687,433,085.8	1.91	7,056,000,000
Flow: GPD/MW	137	1,385,121.179	4,991,663.852	0.013	58,074,074.07

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Recirculating Cooling Water Systems

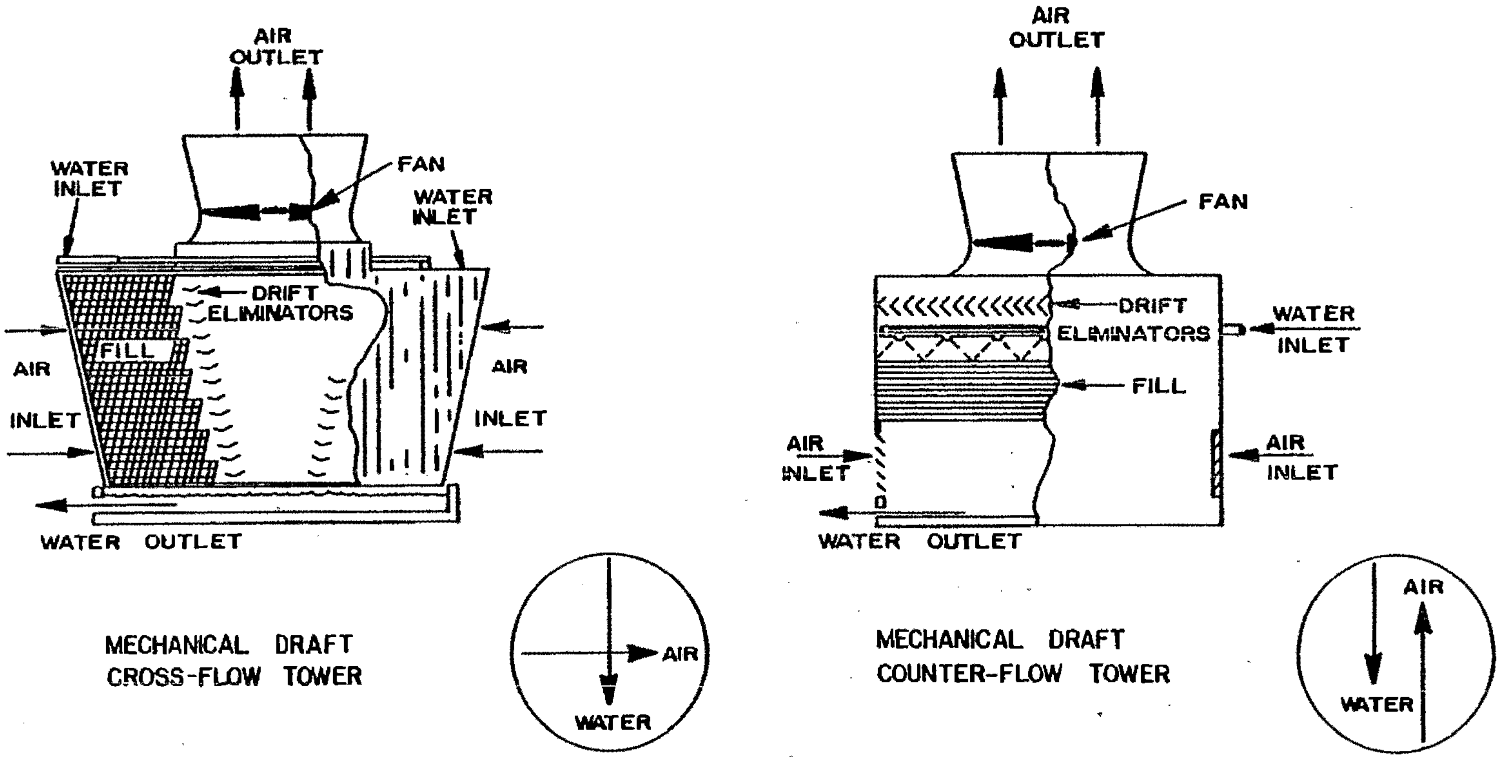
In a recirculating cooling water system, the cooling water is withdrawn from the water source and passed through the condensers several times before being discharged to the receiving water. After each pass through the condenser, heat is removed from the water. The heat is removed from the cooling water by three major methods: cooling ponds or cooling canals, mechanical draft evaporative cooling towers, and natural draft evaporative cooling towers.

Cooling ponds are generally most appropriate in relatively dry climates and in locations where large land areas are available. In some cases where land area is not readily available, spray facilities have been installed to reduce the needed pond size. Approximately half of the steam electric industry's cooling ponds are in the Southwest (Texas and Oklahoma), a quarter in the Southeast, and the remainder mainly in the Midwest. Cooling ponds normally have a water retention time of 10 days or more and, for a large steam electric plant, usually have a surface area in excess of 500 hectares. Chemical addition requirement for cooling ponds is significantly less than for cooling towers.

The mechanical draft evaporative cooling tower is by far the most popular cooling method for recirculating cooling water in large steam electric powerplants. The mechanical draft towers, shown in figure V-3, use fans to move air past the droplets or films of water to be cooled. Evaporation of water into the air stream provides the primary mechanism for cooling.

Like the mechanical draft towers, the natural draft towers rely on water evaporation for cooling effect. However, fans are not used to induce air through the tower. Instead, the tower is designed so that air will naturally flow from the bottom to the top of the tower as a result of density differences between ambient air and moist air inside the tower and the chimney effect of the tower's tall structure. Natural draft towers are often selected over mechanical draft towers in areas where low wet bulb temperatures and high humidity prevail. A sketch of this type of tower is shown in figure V-4.

More than 120 natural draft cooling towers were installed or planned by 1976 (6). The first towers installed in this country were concentrated in the Appalachian Mountains as a solution to the problem of getting plumes up and out of local valleys. As of 1976, however, towers were in operation or on order in 23 states. While the number of units may represent as little as 20 percent of the total number of cooling towers at powerplants, the megawatt capacity they represent is far higher since natural draft towers usually are constructed for the larger, newer plants. Natural draft cooling towers are expected to account for almost 50 percent of new generating capacity requiring cooling towers. All of the hyperbolic natural draft cooling towers built in the United States to date have been of concrete construction. Cooling tower fill can be made of polyvinyl chloride, asbestos cement, ceramic or wood.


AIR OUTLET
WATER INLET
FAN
WATER INLET
DRIFT ELIMINATORS
FILL
AIR INLET
AIR INLET
WATER OUTLET
AIR
WATER
AIR OUTLET
FAN
DRIFT ELIMINATORS
WATER INLET
FILL
AIR INLET
AIR INLET
WATER OUTLET
AIR
WATER

MECHANICAL DRAFT CROSS-FLOW TOWER

MECHANICAL DRAFT COUNTER-FLOW TOWER

Figure V-3
MECHANICAL DRAFT COOLING TOWERS (4)

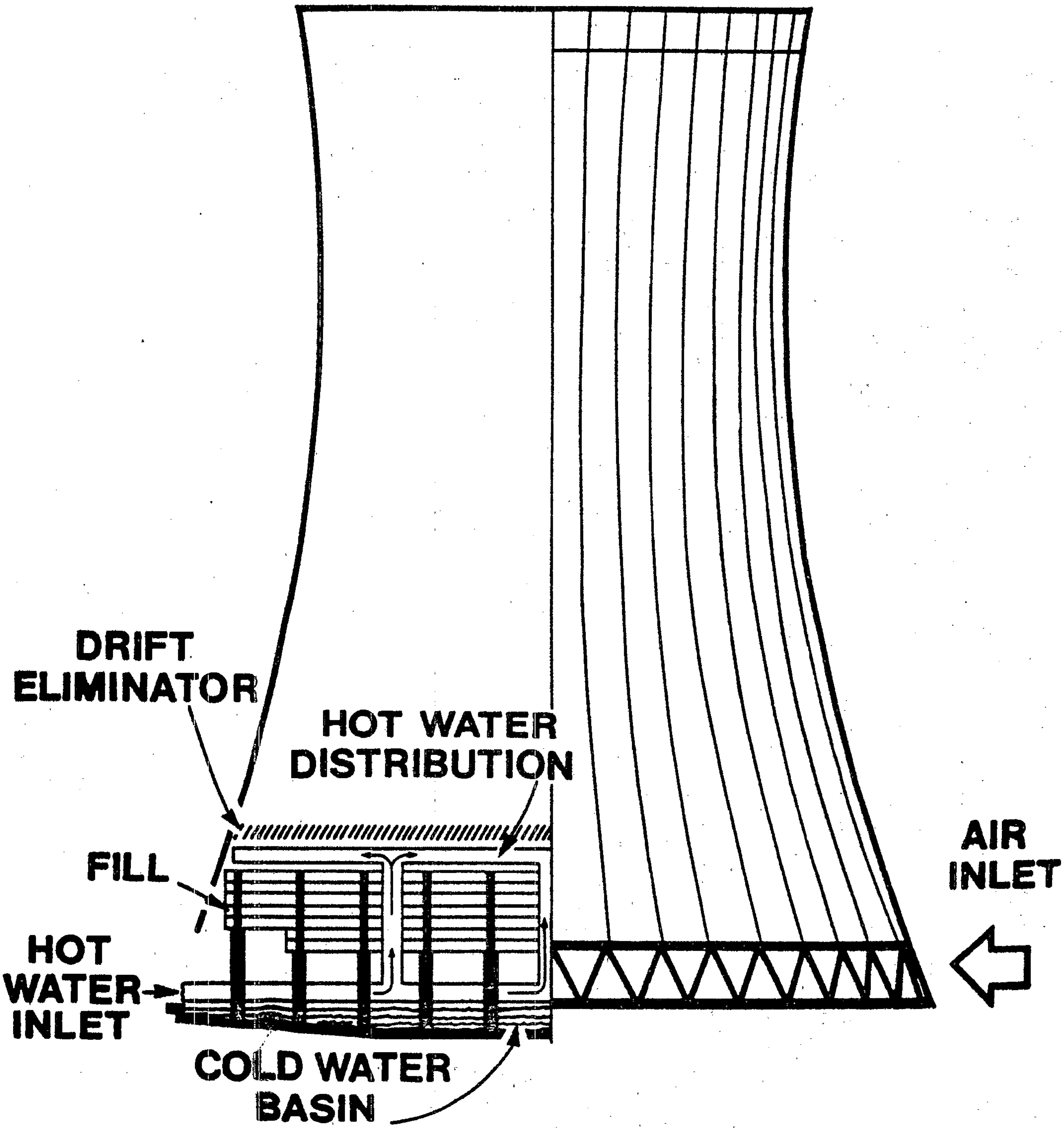

DRIFT ELIMINATOR
HOT WATER DISTRIBUTION
FILL
AIR INLET
HOT WATER INLET
COLD WATER BASIN

Figure V-4
NATURAL DRAFT EVAPORATIVE COUNTERFLOW COOLING TOWER (5)

The water that evaporates from a recirculating cooling water system in cooling ponds or cooling towers results in an increase in the dissolved solids content of the water remaining in the system; thus, the dissolved solids concentration will tend to build up over time and will eventually, if left unattended, result in the formation of scale deposits. Scaling due to dissolved solids buildup is usually maintained at an acceptable level through use of a bleed stream called cooling tower blowdown. A portion of the cooling water in the system is discharged via this stream. The discharged water has a higher dissolved solids content than the intake water used to replace the discharged water, so the dissolved solids content of the water in the system is reduced. Table V-5 presents a statistical analysis of cooling tower blowdown based on 308 data.

In some recirculating systems, chemical additives that inhibit scale formation are added to the recirculating water. These additives are discharged in the cooling tower blowdown.

Chlorination

Biofouling occurs when an insulating layer of slime-forming organisms forms on the waterside of the condenser tubes, thus inhibiting the heat exchange process. The slime-forming organisms consist of fungi, bacteria, iron bacteria, and sulfur bacteria. The exact mechanics of biofouling are not fully understood, but the steps are believed to consist of a roughening of the metal surfaces by abrasion; attachment of bacteria and protozoa; entrapment of particulate matter by the slime growth; and the deposition of successive layers of slime-forming organisms and particulate matter (3).

Chlorination is the most widely practiced method of biofouling control for both once-through and recirculating cooling water systems. Based on the '308' data and Federal Power Commission data, about 65 percent of the 842 steam electric plants use chlorine for biofouling control. The remaining plant either do not have a significant biofouling problem or use a method of control other than chlorine. If the intake water has certain characteristics, e.g., high suspended solids concentration or low temperature, biofouling is not a problem with once-through cooling water systems. With recirculating cooling water systems, chlorination may still be required in order to protect the cooling tower. The alternatives to chlorine include other oxidizing chemicals, nonoxidizing biocides, and mechanical cleaning. None of these alternatives are widely used at this time, so chlorination is clearly the predominant method of biofouling control.

The properties of chlorine that make it an effective biofouling control agent are precisely the properties which cause environmental concern. The addition of chlorine to water causes the formation of toxic compounds and chlorinated organics which may be priority pollutants. The available information on the reaction mechanisms and products of chlorine with fresh and saline waters is summarized in the following two subsections.

Table V-5

COOLING TOWER BLOWDOWN
(308 Questionnaire)

Variable	Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: Coal*					
Flow: GPD/plant	82	2,232,131	5,452,632.6	0.00	40,300,000
GPD/MW	82	2,973.251	7,308.87	0.00	63,056.68
Fuel: Gas*					
Flow: GPD/plant	120	315,951.9	505,504.6	0.00	2,882,880
GPD/MW	119	3,080.131	4,851.049	0.00	26,208.00
Flow: Oil*					
Flow: GPD/plant	47	274,193.2	584,273.3	0.00	3,200,000
GPD/MW	47	1,862.413	3,428.478	0.00	16,712.00

---

*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Fresh Water

When chlorine is dissolved in water, hypochlorous acid and hydrochloric acid are formed:

$$Cl_2 + H_2O \rightleftarrows HOCl + HCl \qquad (1)$$

The reaction occurs very rapidly. In dilute solutions with pH levels greater than 4, the equilibrium is displaced far to the right; therefore, very few chlorine molecules (Cl_2) exist in solution. Hypochlorous acid is a weak acid that particularly dissociates in water to the hydrogen ion and the hypochlorite ion:

$$HOCl \rightleftarrows H^+ + OCl^- \qquad (2)$$

The equilibrium of this reaction is a function of pH as shown in figure V-5. As pH increases, the ratio of hypochlorite ion to hypochlorous acid increases. The concentrations of hypochlorous acid plus hypochlorite ion in solution is termed free available chlorine.

Chlorine may be applied to water not only in the pure Cl_2 form but also in compound form, usually as hypochlorite. Hypochlorites are salts of hypochlorous acid. The two most commonly used hypochlorites are calcium hypochlorite, a solid, and sodium hypochlorite, a liquid. When sodium hypochlorite is dispersed in water, hypochlorous acid and sodium hydroxide are formed:

$$NaOCl + H_2O \rightleftarrows HOCl + NaOH \qquad (3)$$

Hypochlorous acid then partially dissociates in accordance with Equation 2; therefore, whether chlorine gas or hypochlorite are added to water, the end chlorine-containing products are hypochlorous acid and hypochlorite ion.

Both hypochlorous acid and hypochlorite ion are potent oxidizing agents. The source of this oxidizing potential is the chlorine that, at a oxidation state of +1, can accept two electrons in being reduced to the -1 state. Hypochlorous acid is superior to hypochlorite ion as a biocide. The primary reason for this superiority is the relative ease with which hypochlorous acid can penetrate biological organisms. As a result of the biocidal efficiency of hypochlorous acid, an equilibrium shifted to the left in Equation 2 is preferred in most applications. The achievement of such an equilibrium position is aided by using chlorine since one of the reaction products, hydrochloric acid, lowers the pH of the water; but the achievement of this equilibrium position is impeded when using hypochlorite since one of the reaction products, sodium hydroxide, raises the pH of the water.

Since hypochlorous acid is an oxidizing agent, a considerable amount of free available chlorine may be consumed in reactions with inorganic-reducing materials in water before any biocidal effect is accomplished. Cyanide, hydrogen sulfide, iron, and manganese are

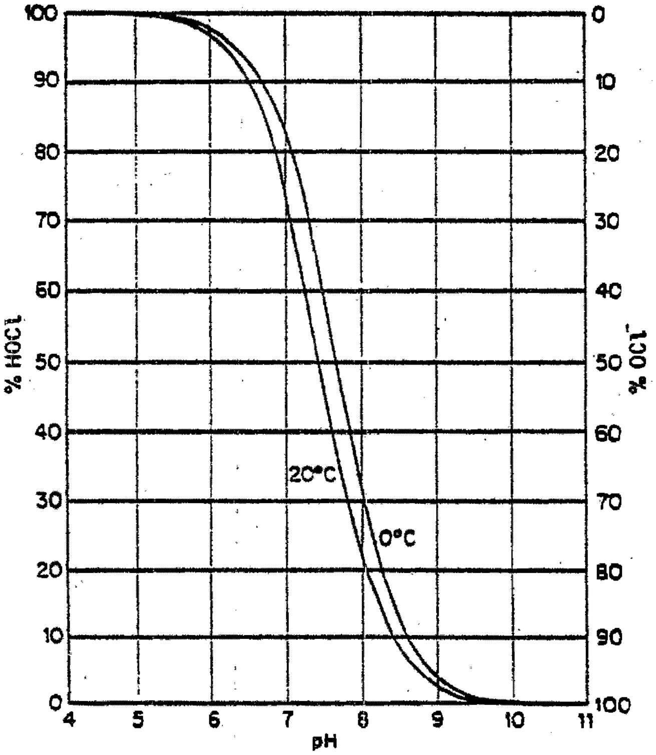


Figure V-5

EFFECT OF pH ON THE DISTRIBUTION OF HYPOCHLOROUS ACID AND HYPOCHLORITE ION IN WATER

Reprinted from Chemistry for Sanitary Engineers by C. N. Sawyer and P. L. McCarty by permission of McGraw-Hill, Inc., Year of first publication: 1967.

among the substances which can be oxidized by hypochlorus acid. In these reactions the Cl^+ in hypochlorus acid is reduced to Cl^- which has no biocidal capability. The consumption of hypochlorous acid by inorganic-reducing materials is termed chlorine demand. The demand for chlorine by these substances must be satisifed before hypochlorous acid is available for biocidal activity.

When sufficient hypochlorous acid is present to exceed chlorine demand, the acid will react with ammonia and organic materials. The reaction of ammonia with hypochlorous acid forms monochloramine and water:

$$NH_3 + HOCl \rightleftarrows NH_2Cl + H_2O \quad (4)$$

This reaction occurs when the weight ratio of chlorine to ammonia is less than or equal to 5:1. Monochloramine is a weak biocide. The reactions of organic materials with hypochlorous acid can be divided into two groups: reactions with organic nitrogen and reactions with all other organic compounds. Compounds which contain organic nitrogen are complex; therefore, the chemistry of chlorination of organic nitrogen compounds is complex. The products of the reactions of diverse organic nitrogen compounds with hyprochlorous acid are grouped under the general term complex organic chloramines. The chemistry of chlorination of other organic compounds is also complex. The products of chlorination of other organic compounds are grouped under the general term chlorine substitution and addition products. The organic chloramines and the chlorine substitution and addition products are weak biocides. The chlorine contained in these compounds and in monochloramine is called combined chlorine residual. The word "residual" denotes that this is the chlorine remaining after satisfaction of chlorine demand, while the word "combined" denotes that the chlorine is tied up in compounds.

Further addition of hypochlorous acid so that the weight ratio of chlorine to ammonia exceeds 5:1 results in the conversion of some of the monochloramine to dichloramine:

$$NH_2Cl + HOCl \rightleftarrows NHCl_2 + H_2O \quad (5)$$

As the weight ratio of chlorine to ammonia increases to 10:1, the dichloramine and the organic chloramines and chlorine substitution and addition products begin to decompose. The exact mechanism and products of this decomposition are still incompletely defined. The decomposition consumes hypochlorous acid, so a chlorine demand is again exerted. The decomposition also decreases the combined chlorine residual level. Decomposition ceases at a weight ratio of chlorine to ammonia of 10:1. At this point, the combined available chlorine residual consists of approximately equal amounts of monochloramine and dichloramine. Like monochloramine, dichloramine is a weak biocide.

As the weight ratio of chlorine to ammonia proceeds to 20:1 through addition of hypochlorous acid, the conversion of monochloramine to *dichloramine* is greatly speeded and some dichloramine is converted to trichloramine, also called nitrogen trichloride:

$$NHCl_2 + HOCl \rightleftarrows NCl_3 + H_2O \qquad (6)$$

Regardless of the form of the combined available chlorine residual, the amount of the residual remains constant at the level present when the chlorine to ammonia weight ratio was 10:1. The quantity of hypochlorous acid added that is not involved in the chloramine reactions is, therefore, present as free available chlorine residual. Hypochlorous acid is, as previously stated, a powerful biocide.

The effect of various impurities in water on the disinfecting power of hypochlorous acid, described by the preceding series of equations, is illustrated in figure V-6. Total available chlorine residual, which includes both combined available chlorine residual and free available chlorine residual, is the measure of total biocidal power. As hypochlorous acid is added to water, the total available chlorine residual passes through four stages. In the first stage, no residual is formed because chlorine is being reduced by inorganic materials. In the second stage, a residual, consisting of only combined available chlorine, is formed and continuously increases as monochloramine, organic chloramines, and chlorinated organics are formed. In stage three, the residual, still consisting of only combined available chlorine, decreases as monochloramine is converted to dichloramine and the dichloramine and the organic compounds undergo further reactions. In the fourth stage, the residual increases continuously. The residual in this stage consists of both combined available chlorine and free available chlorine. In most water treatment operations, sufficient hypochlorous acid is provided to operate in stage four in order to take advantage of the biocidal power of hypochlorous acid.

A great deal of research has been conducted on the formation of chlorinated organics in fresh water. Some of the chlorinated organics are in the list of 129 priority pollutants (i.e., bromoform and chloroform). One of the experiments to examine chlorination of organics resulting from chlorinated cooling waters was performed by Jolley, et al (7). Over 50 chlorinated organics were isolated from concentrates of Watts Bar Lake water and Mississippi River water which were chlorinated at concentrations of 2.1 mg/l (75 minutes reaction time) and 3.4 mg/l (15 minutes reaction time). The chlorinated organics formed were in ppb concentrations.

In view of the finding of the National Organics Reconnaissance Survey that halogenated organics in raw and finished drinking water are widespread and distributed with a frequency shown in figure V-7, EPA Municipal Environmental Research Labs (8) sought to investigate the mechanism for the formation. Suspecting humic substances to be the precursors, they tested this hypothesis. At concentrations of humic acid representing the non-volatile total organic carbon (NVTOC) concentrations found in the Ohio River (3 mg/l), they observed that the rate of trihalomethane formation was similar to that observed in Ohio River water.

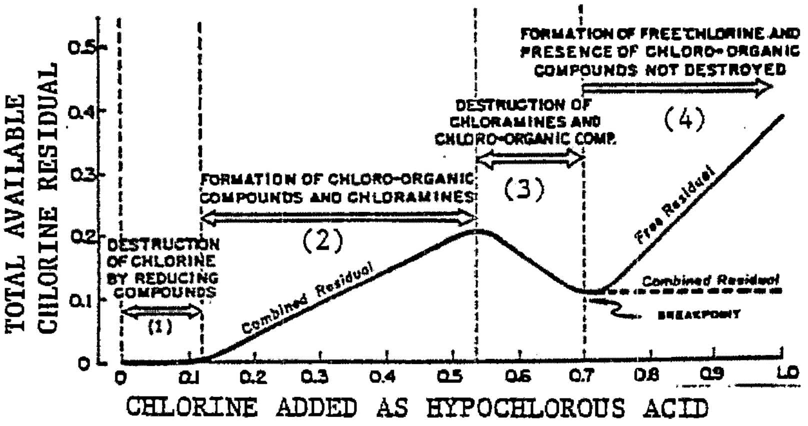


Figure V-6

EFFECT OF IMPURITIES IN WATER ON TOTAL AVAILABLE CHLORINE RESIDUAL

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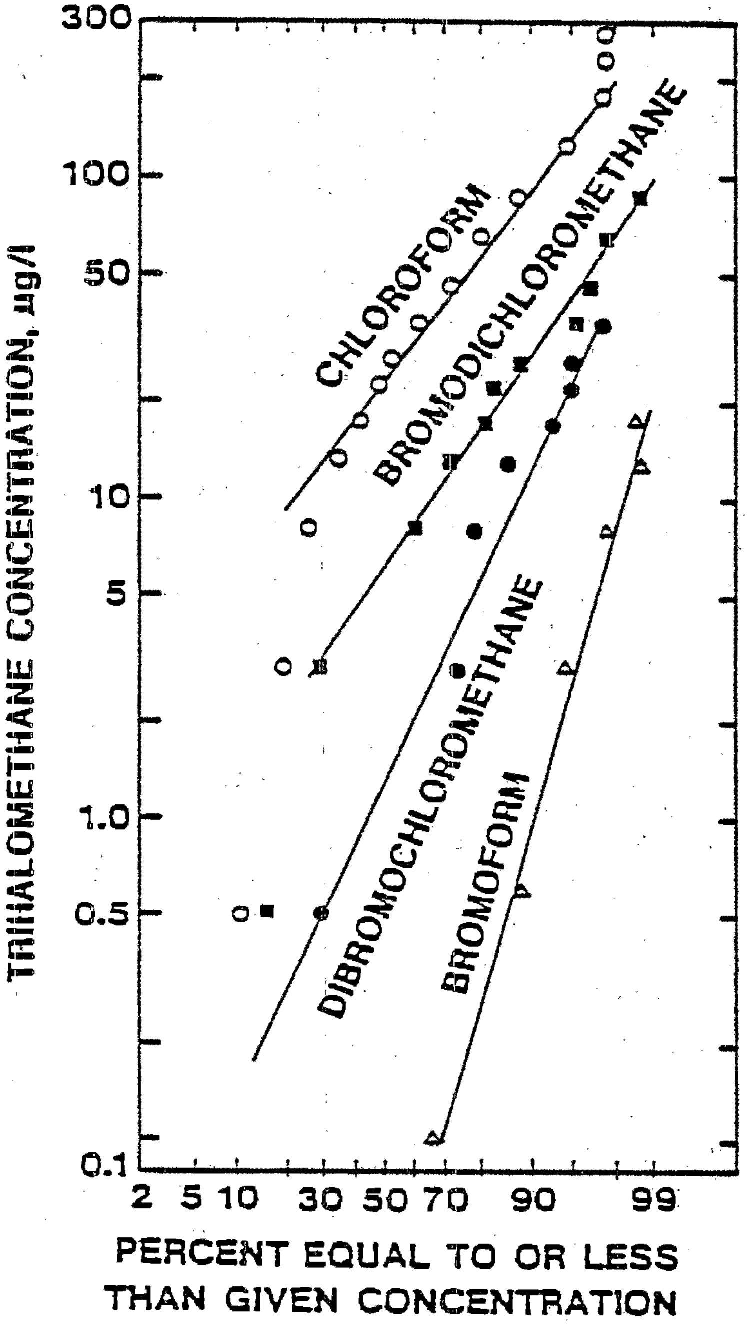

Figure V-7

FREQUENCY DISTRIBUTION OF HALOGENATED ORGANICS IN RAW AND FINISHED DRINKING WATER (8)

The major mechanism for trihalomethane reactions in natural waters is the haloform reaction (9) that is a base catalyzed series of halogenation and hydrolysis reactions which occur typically with methyl ketones or compounds oxidizable to that structure. Humic and fulvic substances have been postulated as precursors to trichloromethane formation. Humic materials are composed of aromatic and alicyclic moieties containing alcoholic, carbonyl carboxylic, and phenolic functional groups, which can participate in trihalomethane formation by ionizing to form carbonions rapidly.

Unfortunately, data on the formation of trihalomethanes in cooling water effluents is not readily available. Several of the variables which influence chloroform formation have been investigated by the Louisville Water Company (10). A conventional treatment process of sedimentation, coagulation with alum, softening, recarbonization, and filtration is practiced. Primary disinfection is accomplished by chlorination at the head of the coagulation process. The chlorine residual leaving the plant is approximately 2.0 ppm. The correlation between total trihalomethanes and water temperature is shown in figure V-8. It is evident that seasonal variation in influent water temperature could vary the effluent chloroform concentration by a factor of 2-3 times. There are marked increases in chloroform formation with increases in pH as shown in figure V-9. Figure V-10 shows the effect of contact time on chloroform formation.

Saline Water

When chlorine gas is dissolved in saline water, the chemical reactions which occur initially are identical to the reactions which occur when chlorine gas is dissolved in fresh water. Once hypochlorous acid and hypochlorite ion are in equilibrium in solution, the bromide present in saline water is oxidized and hypobromous acid and hypobromite ion, respectively, are formed:

$$\mathrm{HOCl} + \mathrm{Br} \rightleftarrows \mathrm{HOBr} + \mathrm{Cl} \qquad (7)$$

$$\mathrm{Br}^{-} + 3\mathrm{ClO} \rightleftarrows \mathrm{BrO}^{-3} + 3\mathrm{Cl}^{-} \qquad (8)$$

The oxidiaation occurs because chlorine has a higher oxidation potential than bromine. The equilibriums in these reactions are normally displaced to the right; hence, hypobromous acid and hypobromite ion are more prevalent in solution than hypochlorous acid and hypochlorite ion.

The four oxidizing compounds: hypochlorous acid, hypochlorite ion, hypobromous acid, and hypobromite ion are believed to behave in saline water similarly to hypochlorous acid and hypochlorite ion in fresh water. The reactions and the reaction products in each of the four stages described for fresh water are not conclusively defined for saline water. The presence in saline water of numerous chemical species not found in fresh water leads to many side reactions triggered by the four oxidizing compounds. These side reactions

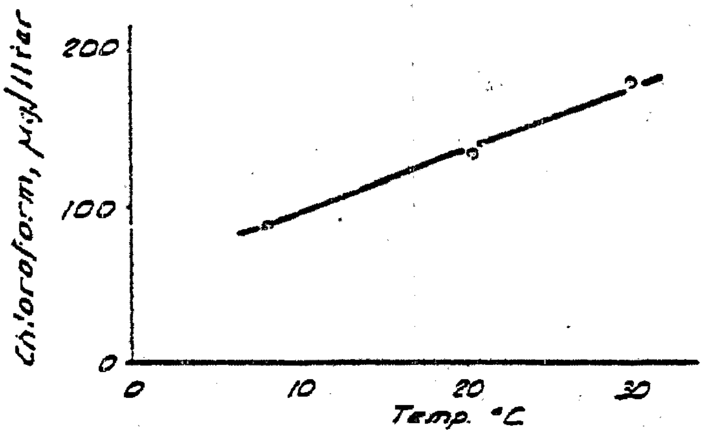

Figure V-8

EFFECT OF WATER TEMPERATURE ON THE

CHLOROFORM REACTION

Reprinted from Hubbs, S.A., et al., "Trihalomethane Reduction at the Louisville Water Company," Louisville Water Company, Louisville, KY, undated.

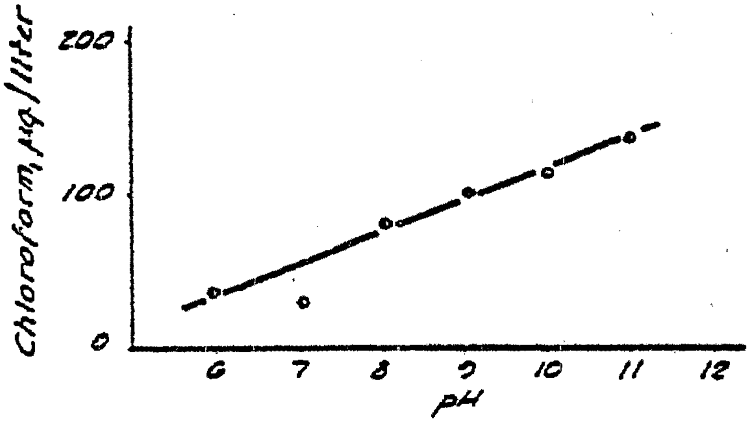

Figure V-9

EFFECT OF pH ON THE CHLOROFORM REACTION

Reprinted from Hubbs, S. A., et al., "Trihalomethane Reduction at the Louisville Water Company," Louisville Water Company, Louisville, KY, undated.

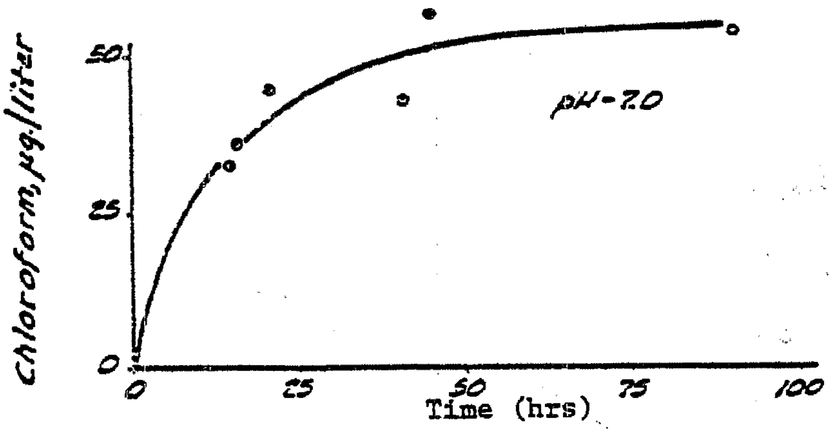

Figure V-10

EFFECT OF CONTACT TIME ON THE CHLOROFORM REACTION

Reprinted from Hubbs, S. A., et al., "Trihalomethane Reduction at the Louisville Water Company," Louisville Water Company, Louisville, KY, undated.

obscure the main reactions which result in the difficulty in defining the primary reactions and reaction products. In spite of this difficulty, some progress has been made in defining reaction products, particularly in Stage 4. In this stage, the free residual probably contains the four oxidizing compounds and the combined residual probably contains chloramines, bromamines, chloro-organics, and bromo-organics.

Bean, et al. (11), chlorinated Seguim Bay waters at a rate of 1-2 mg/l chlorine for approximately 2 hours. This is relatively pristine water with approximately 1 mg/l TOC. Principle reaction products were bromoform (30 mg/l) with smaller quantities of dibromomethane and traces of dichloromethane.

Carpenter (12) found that bromoform, and to a lesser extent, chlorodibromomethane were formed upon chlorination of Biscayne Bay waters. Typically, organic constituents range from 9-12 ppb dissolved organic carbon. Chlorination to 1 mg/l produced 36 ppb $CHBr_3$ in unfiltered water and 43 ppb $CHBr_3$ centrifuged water. It is postulated that chlorine reacts with the particulate matter and prevents oxidation of bromine to a certain extent in the former case.

Corrosion Products

Corrosion is an electrochemical process that occurs when metal is immersed in water. A difference in electrical potential between different parts of the metal causes a current to pass through the metal between the anode, the region of lower potential, and the cathode, the region of higher potential. The migration of electrons from the anode to the cathode results in the oxidization of the metal at the anode and the dissolution of metal ions into the water (13).

Most metals rely on the presence of a corrosion products film to impart corrosion protection. In the case of copper alloys, which are used extensively in powerplant condensers, this film is usually Cu_2O. As a result, copper can usually go into the corrosion product film or directly into solution as an ion or a precipitate in the initial stages of condenser tube corrosion. As corrosion products form and increase in thickness, the corrosion rate decreases continually until steady state conditions are achieved. The data presented in table V-6 lend support to the corrosion product film theory as applied to condenser tubes. The plant that was sampled had three units. Unit 3 had just begun operation and contributed the most copper to the cooling water. Unit 1 had been in operation for a longer period of time and contributed the least amount of copper to the cooling water. Unit 2 was not considered in the comparison because mechanical cleaning was used to control biofouling which artificially increased the copper contribution to the cooling water (14).

Waters high in dissolved solids are more conductive; therefore, plants using saline water for cooling should have higher metals concentrations in the cooling water discharge than plants using fresh water. Popplewell and Hager (15) observed that the long term

Table V-6

COPPER CORROSION DATA (14)

Condenser	Material	Comment	Copper Added to Cooling Water by Passing Through the Condenser* Soluble (ug/l)	Particulate (ug/l)
Unit 1	Aluminum-brass 76-79 percent copper	Considered to be equilibrated with the environment	No statistically significant addition	1.28
Unit 2	90/10 copper nickel alloy	Mechanical anti-fouling system was used	6.70	7.76
Unit 3	90/10 copper nickel alloy	Had been operating intermittently for only a few months	11.8	1.8

---

*Average of hourly samples over a 24 hour sampling period; corrected for copper concentrations at the intake.

corrosion rate of alloy 706 (90/10-copper/nickel) does not differ significantly in different environments. A summary of these results is shown in table V-7. Copper release is more a function of flow rate than it is of salt content of makeup water. A study was undertaken by a utility (16) to determine concentrations of cadmium, chromium, copper, nickel, lead, and zinc in the influents and effluents of eight coastal generating stations. The composite data in table V-8 for all eight plants sampled shows that in 11 of the 12 available comparisons, the median difference between effluent and influent concentration was positive, suggesting a net addition of trace elements as a result of corrosion. However, only copper in the dissolved state and zinc in the suspended were increased in excess of 0.1 ppb. The data from these two studies do not indicate higher metal concentrations in saline cooling water compared to fresh cooling water and, regardless of the type of water, do not indicate that significant increases in metals concentrations are occuring because of cooling system corrosion.

Data on soluble copper concentrations in the recirculating cooling water systems at three plants are summarized in table V-9. The soluble copper concentrations in the intake water are also provided as a baseline. Copper concentrations increase markedly in the tower basin and the drift and increase dramatically in sludge in the tower basin (15). Based on this data, it appears that corrosion products are more of a problem in cooling tower blowdown (tower basin in table V-9) than in once-through cooling water discharge. The concentration of pollutants (via evaporation) in recirculating systems probably accounts for most of the difference in the level of metals observed between once-through discharge and cooling tower blowdown.

Products of Chemical Treatment

Chemical additives are needed at some plants with recirculating cooling water systems in order to prevent corrosion and scaling. Chemical additives are also occasionally used at plants with once-through cooling water system for corrosion control.

Scaling occurs when the concentration of dissolved materials, usually calcium and magnesium containing species, exceeds their solubility levels. Solubility levels are influenced by, among other things, water temperature and pH. The addition of scaling control chemicals allows a higher dissolved solids concentration to be achieved before scaling occurs; therefore, the amount of blowdown required to control scaling can be reduced. Control of scaling is an important plant cooling systems operational consideration. Severe scaling can drastically alter cooling systems fluid flow characteristics and result in reduced heat transfer, high pressure drops, and other undesirable effects.

Chemicals added to once-through cooling water to control corrosion or to recirculating cooling water to control corrosion and scaling will usually be present in the discharges. A list of chemicals commonly used to control corrosion and scaling is presented in table V-10 (17).

Table V-7

ONE YEAR STEADY STATE CORROSION RATES FOR ALLOY 706 DETERMINED EXPERIMENTALLY (15)

New Haven Tap Water	Brackish Water 0.1% NaCl	Salt Water 3.4% NaCl	
0.1 mils/yr	0.1 mils/yr	0.1 mils/yr	0.2 mils/yr
at velocity of 7 ft/sec	at velocity of 7 ft/sec	at velocity of 7 ft/sec	at velocity of 12 ft/sec

Table V-8

SELECTED PRIORITY POLLUTANT CONCENTRATIONS IN SEAWATER BEFORE AND AFTER PASSAGE THROUGH ONCE-THROUGH COOLING WATER SYSTEM (16)

	Median Influent Concentration (ppb)		Net Concentration Change (Effluent-Influent) (ppb)	
Metal	Dissolved	Particulate	Dissolved	Particulate
Cd	0.06	0.006	0.034	0.005
Cr	0.16	0.200	(0.010)*	0.097
Cu	0.80	0.320	0.21	0.10
Ni	0.44	0.160	0.10	0.004
Pb	0.14	0.24	0.04	0.07
Zn	0.20	0.48	0.09	0.17

---

*Negative value.

Table V-9

SOLUBLE COPPER CONCENTRATIONS IN RECIRCULATING COOLING WATER SYSTEMS (15)

Location of sample	Plant 1 2 years operation		Plant 2 1 year operation		Plant 3 1 week operation	
	pH	ppb	pH	ppb	pH	ppb
River influent	7.0	1.8	6.95	1	-*	-*
Tower Basin	6.45	88	6.6	35	6.9	75
Tower basin mud	-*	560,000	-*	670,000	-*	-*
Tower drift	6.43	76	6.5	34	-*	-*

---

*Measurement not taken.

Table V-10

COMMONLY USED CORROSION AND SCALING CONTROL CHEMICALS (17)

Benzotriazole and its sodium salt
*Chromic Acid
Nitrilo-tris acetic acid and its alkali metal and ammonium salts
Organophosphorous Antiscalants including 1-Hydroxyethylidene-1, 1-diphosphonic acid, Nitrilo-tri (methylenephosphonic acid) (and the alkali metal and ammonium salts of each), and Polyolphosphate esters of low molecular weight
Potassium hydroxide
Sodium bisulfate
Sodium carbonate
*Sodium dichromate
*Sodium chromate
Sodium hexametaphosphate
Sodium hydroxide
Sodium mercaptobenzothiazole
Sodium molybate
Sodium nitrate
Sodium nitrite
Sodium phosphate (mono-, di-, tri-)
Sodium silicates
Sodium tetraborate
Sodium tripolyphosphate
Sulfamic acid
Sulfuric acid
Tetrasodium pyrophosphate
Tetrapotassium pyrophosphate
Ethylenediamine tetra-acetic acid and its alkali metal and ammonium salts
Tolyltriazole
*Zinc chloride

Table V-10.(Continued)

COMMONLY USED CORROSION AND SCALING CONTROL CHEMICALS (17)

*Zinc oxide
*Zinc sulfate
Tannins
Sodium Boro-polyphosphate
*Sodium Zinc Polyphosphate
*Calcium Zinc Polyphosphate
Sodium Acid Pyrophosphate
Phosphoric acid
Ethylene diamine tetrakis (methylene phosphonic acid) and its alkali metal and ammonium salts
Hexamethylene diamine tetrakis (methylene phosphonic acid) and its alkali metal and ammonium salts
Diethylene triamine pentakis (methylene phosphonic acid) and its alkali metal and ammonium salts
Sodium polystyrene sulfonate and copolymers
Carbon dioxide
Monobutyl esters of polyethylene - and polypropylene glycols
Acrylamide polymers and copolymers
Polyoxypropylene glycols (min. mol. wt. 1,000)
Sodium carboxymethylcellulose
Sodium lignosulfonates
Sodium polyacrylates and polyacrylic acids
Sodium polymethacrylates
Styrene - maleic anhydride copolymers
Polyethylenimines
Sodium citrate
Alkyphenoxy polyethoxy ethanols
Dioctyl sodium sulfosuccinate

Table V-10 (Continued)

COMMONLY USED CORROSION AND SCALING CONTROL CHEMICALS (17)

Poly - (amine-epichlorohydrin) condensates
Poly - demethyl, diallyl ammonium chlorides
Poly - (amine-ethylene dichloride) condensates

NOTE: In many cases either sodium or potassium salts are in use.

*Indicates that the compound is known to contain a priority pollutant. Some of the other compounds may contain or may degrade into priority pollutants but no data was available to make a definite determination.

Those compounds which are priority pollutants are marked with an asterisk to the left of the compound name. Chromium and zinc are the active components of most of the popular corrosion inhibitors. Both these metals are inorganic priority pollutants. The solvent and carrier components which may be used in conjunction with scaling and corrosion control agents are listed in table V-11 (17). The pollutants which were reported as present in recirculating cooling water on the 308 data base forms are found in table V-12. In addition to the chemicals listed in this table, acrolein and asbestos have been reported.

Products of Asbestos Cooling Tower Fill Erosion

The fill material in natural draft cooling towers is frequently asbestos cement. Erosion of the fill material can cause discharge of asbestos in cooling water blowdown. Table V-13 shows the test results for detection of asbestos fibers in the waters of 18 cooling systems. Baseline data on chrysotile asbestos concentrations in makeup water are also contained in the table. Seven of the 18 sites contained detectable concentrations of chrysotile asbestos in the cooling tower waters at the time of sampling. Most of the samples containing detectable chrysotile were samples of basin water. Data in the last three columns of the table for Site 3 indicate that a settling pond or lagoon interposed between the cooling towers and the receiving water removes asbestos since it was not detectable in the effluent (4).

Sampling Programs Results

Once-Through Cooling Water Systems

Three plants that use only once-through cooling water systems were sampled during the screening phase of the sampling program. Table V-14 present trace metal data for these plants from the screening program. The duration of chlorination at all three plants did not exceed 2 hours per day. Net increases were observed for antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, and phenol. However, net increases were greater than 10 ppb only for arsenic, cadmium, nickel, selenium, and phenol. Only in the case of arsenic was the net increase greater than 25 ppb.

Eleven plants with once-through cooling water systems were sampled as part of the verification program and the surveillance and analysis sampling efforts. The analytical results are presented in Table V-15. Four of these plants have estuarine or salt water intakes, and the remaining seven plants have fresh water intakes. Samples were collected only during the period of chlorination. The samples were analyzed for all the organic priority pollutants except the pesticides, and for total organic carbon and total residual chlorine. Only the organic priority pollutants which were detected are shown. Analysis for total residual chlorine (TRC) was performed at nine of the plants.

Table V-11

SOLVENT OR CARRIER COMPONENTS THAT MAY BE USED IN CONJUNCTION WITH SCALING AND CORROSION CONTROL AGENTS (17)

Dimethyl Formamide
Methanol
Ethylene glycol monomethyl ether
Ethylene glycol monobutyl ether
Methyl Ethyl Ketone
Glycols to Hexylene Glycol
*Heavy aromatic naphtha
Cocoa diamine
Sodium chloride
Sodium sulfate
Polyoxyethylene glycol
Talc
Sodium Aluminate
Monochlorotoluene
Alkylene oxide - alcohol glycol ethers

*Indicates that the compound is known to contain a priority pollutant. Some of the other compounds may contain or may degrade into priority pollutants but no data was available to make a definite determination.

Table V-12

POLLUTANTS REPORTED ON 308 FORMS IN COOLING TOWER BLOWDOWN

Compound Name	Number of Plants Reporting Presence
Antimony and compounds	3
Arsenic and compounds	2
Cadmium and compounds	3
Chlorinated phenols	7
Chloroform	1
Chromium and compounds	36
Copper and compounds	8
EDTA	6
Lead and compounds	3
Mercury and compounds	2
Nickel and compounds	3
Pentachlorophenol	9
Phenol	2
Selenium and compounds	2
Silver and compounds	2
Thallium and compounds	2
Vanadium	2
Zinc and compounds	31

Table V-13

ASBESTOS IN COOLING TOWER WATERS (4)

			Asbestos, fibers/liter of μg/g (sed)*								
			Makeup Water		Basin Water		Blowdown		Other		
Site No.	Sampling Date	Replicates	Lower Limit of Detection	Conc.	Lower Limit of Detection	Conc.	Lower Limit of Detection	Conc.	Sample	Lower Limit of Detection	Conc.
1	26 May 77	a	6.3×10^{4}	B.D.L.	8.4×10^{4} sup	B.D.L.	6.3×10^{4} sup	B.D.L.			
					5.2×10^{6} sed	B.D.L.	6.4×10^{6} sed	B.D.L.			
		b	6.3×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L.	6.3×10^{4} sup	B.D.L.			
					4.8×10^{6} sed	B.D.L.	6.4×10^{6} sed	B.D.L.			
		c	6.3×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L	6.3×10^{4} sup	B.D.L.			
					83×10^{6} sed	44×10^{8}	7.5×10^{6} sed	B.D.L.			
2	26 May 77	a	6.3×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L.			Settling-pond effluent	6.3×10^{4} sup	B.D.L.
					11×10^{6} sed	B.D.L.			" "	4.9×10^{6} sed	B.D.L.
		b	6.3×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L.			" "	6.3×10^{4} sup	B.D.L.
					9.1×10^{6} sed	B.D.L.			" "	5.6×10^{6} sed	B.D.L.
		c	6.3×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L.			" "	6.3×10^{4} sup	B.D.L.
					7×10^{6} sed	B.D.L.			" "	4.8×10^{6} sed	B.D.L.
									Sediment from sump	2.1×10^{6} sed	B.D.L.
3	26 May 77	a	8.4×10^{4}	B.D.L.	8.4×10^{4} sup	B.D.L.	8.4×10^{4} sup	B.D.L.	Lagoon effluent	8.4×10^{4}	B.D.L.
					5.2×10^{6} sed	B.D.L	8.4×10^{6} sed	B.D.L.	" "		
		b	8.4×10^{4}	B.D.L.	8.4×10^{4} sup	B.D.L	8.4×10^{4} sup	0.92×10^{6}	" "	8.4×10^{4}	B.D.L.
					6.4×10^{6} sed	B.D.L.	7×10^{6} sed	B.D.L.	" "		
		c	8.4×10^{4}	B.D.L.	8.4×10^{4} sup	B.D.L.	2.6×10^{6} sup	110×10^{6}	" "	8.4×10^{4}	B.D.L.
4	25 May 77	a	8.4×10^{4} sup	B.D.L.	6.3×10^{4} sup	B.D.L.	8.7×10^{4}	1.3×10^{6}			
			7×10^{6} sed	B.D.L.	220×10^{6} sed	130×10^{8}					
		b	8.4×10^{4} sup	B.D.L.	8.4×10^{4} sup	B.D.L.	3.4×10^{6}	160×10^{6}			
			8.4×10^{6} sed	B.D.L.	LM sed	<0.5%					
		c	8.4×10^{4} sup	B.D.L.	8.3×10^{4} sup	1.9×10^{6}	1.7×10^{5} sup	B.D.L.			
			7×10^{6} sed	B.D.L.	140×10^{6} sed	78×10^{9}	LM sed	<0.5%			
5	13 May 76	a	1.2×10^{5}	0.5×10^{6}	0.5×10^{6}	B.D.L.	0.8×10^{6}	B.D.L.	Potable water	0.12×10^{6}	B.D.L.
6	Oct 76	a	1.57×10^{5}	B.D.L.	1.57×10^{5}	B.D.L.	1.57×10^{5}	B.D.L.			
		b			1.57×10^{5}	B.D.L.					
6	25 May 77	a	6.3×10^{4}	B.D.L.	8.4×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L.			
							4.0×10^{6} sed	B.D.L.			
		b	6.3×10^{4}	B.D.L.	8.4×10^{4}	B.D.L.	6.3×10^{4} sup	B.D.L.			
							7.0×10^{6} sed	B.D.L.			
		c	6.3×10^{4}	B.D.L.	8.4×10^{4}	B.D.L.	1.5×10^{5}	B.D.L.			
7	6 Jul 76	a	6.3×10^{5}	B.D.L.	1.26×10^{6}	B.D.L.	2.1×10^{6}	B.D.L.	Basin water from MDCT that cools NDCT blowdown	1.26×10^{6}	B.D.L.
7[a]	15 Aug 77	a	6.3×10^{4} sup	B.D.L.	6.3×10^{4}	All B.D.L.	6.3×10^{4}	B.D.L.	" "	2.9×10^{5}	B.D.L.
		b	6.3×10^{4} sup	B.D.L.			6.3×10^{4}	B.D.L.	" "	6.3×10^{4}	B.D.L.
		c	6.3×10^{4} sup	B.D.L.			6.3×10^{4}	B.D.L.	" "	6.3×10^{4}	B.D.L.

Table V-13 (Continued)

ASBESTOS IN COOLING TOWER WATERS (4)

Asbestos, fibers/liter of μg/g (sed)*

			Makeup Water		Basin Water		Blowdown		Other		
Site No.	Sampling Date	Replicates	Lower Limit of Detection	Conc.	Lower Limit of Detection	Conc.	Lower Limit of Detection	Conc.	Sample	Lower Limit of Detection	Conc.
8	9 Jul 76	a	1x10^{5}	B.D.L.	2x10^{5}	B.D.L.	Towers had circulating water but no blowdown (towers not yet "on line")				
		b	1x10^{5}	B.D.L.	1.1x10^{5}	B.D.L.					
		c			1x10^{5}	B.D.L.					
9[b]	2 Sep 76	a	1.88x10^{6}	B.D.L.	1.88x10^{6}	B.D.L.	1.88x10^{6}	37x10^{6}			
		b	1.88x10^{6}	B.D.L.	1.88x10^{6}	B.D.L.	1.88x10^{6}	B.D.L.			
		c	1.88x10^{6}	B.D.L.	1.88x10^{6}	B.D.L.	1.88x10^{6}	B.D.L.			
10	31 Aug 76	a	4.2x10^{5}	B.D.L.	1.26x10^{6}	B.D.L.	1.26x10^{6}	B.D.L.			
		b	6.3x10^{5}	B.D.L.	1.26x10^{6}	B.D.L.	1.26x10^{6}	B.D.L.			
		c	6.3x10^{5}	B.D.L.	1.26x10^{6}	B.D.L.	1.26x10^{6}	B.D.L.			
11	15 Aug 77 (1 of 2 towers)	a	2.3x10^{4}	B.D.L.	6.38x10^{6}	370x10^{6}			Settling-basin effluent	1.8x10^{5}	B.D.L.
		b	2.5x10^{4}	B.D.L.	6.47x10^{6}	330x10^{6}			" "	2.5x10^{5}	B.D.L.
		c	2.9x10^{4}	B.D.L.					" "	6.3x10^{4}	B.D.L.
11	15 Aug 77 (2nd of 2 towers)	a			2.9x10^{5}	B.D.L					
		b			2.5x10^{5}	B.D.L					
		c			6.36x10^{6}	210x10^{6}					
12	16 Aug 77 (Unit 3 tower)	a	6.3x10^{4}	B.D.L.	2.5x10^{5}	B.D.L.			Ash-pond effluent	6.3x10^{4}	B.D.L.
		b	2.3x10^{5}	B.D.L.	1.3x10^{5}	B.D.L.			" "	6.3x10^{4}	B.D.L.
		c	1.2x10^{5}	B.D.L.	5.1x10^{5}	24x10^{6}			" "	2.8x10^{5}	B.D.L.
12	16 Aug 77 (Unit 4 tower)	a			2.5x10^{5}	B.D.L.					
		b			2.3x10^{5}	B.D.L.					
		c			2.4x10^{5}	B.D.L.					
13	17 Feb 76	a	1.2x10^{5}	B.D.L.	2.5x10^{5}	4.3x10^{6}	4.7x10^{5}	B.D.L.	Cooling-tower riser	2.5x10^{5}	1.5x10^{6}
13	28 Apr 76	a	4.7x10^{4}	1.4x10^{5} (amphibole)	2.5x10^{5}	2.5x10^{6}			" "	2.5x10^{5}	B.D.L.
14[c]	7 May 76	a	5.9x10^{5} raw	B.D.L.	1.04x10^{6}	B.D.L.	1.04x10^{6}	B.D.L.			
		b	1.2x10^{5} trtd	B.D.L.			1.04x10^{6}	B.D.L.			
		c					1.04x10^{6}	B.D.L.			
		d					1.04x10^{6}	B.D.L.			
15	20 Jun 77	a	6.3x10^{4}	B.D.L.	6.3x10^{4}	B.D.L.	6.3x10^{4}	B.D.L.	Park reservoir	6.3x10^{4}	B.D.L.
		b	6.3x10^{4}	B.D.L.	6.3x10^{4}	B.D.L.	6.3x10^{4}	B.D.L.	" "	6.3x10^{4}	B.D.L.
		c	6.3x10^{4}	B.D.L.	6.3x10^{4}	B.D.L.	6.3x10^{4}	B.D.L.			
16	26 Aug 77	a	8.4x10^{4} sup	B.D.L.			6.3x10^{4} sup	B.D.L.	Discharge canal	6.3x10^{4} sup	B.D.L.
		b	8.4x10^{4} sup	B.D.L.			6.3x10^{4} sup	B.D.L.	" "	6.3x10^{4} sup	B.D.L.
		c	8.4x10^{4} sup	B.D.L.			6.3x10^{4} sup	B.D.L.	" "	6.3x10^{4} sup	B.D.L.
										LM sed	0.5%[d]

Table V-13 (Continued)

ASBESTOS IN COOLING TOWER WATERS (4)

Site No.	Sampling Date	Replicates	Asbestos, fibers/liter of μg/g (sed)* Makeup Water Lower Limit of Detection	Makeup Water Conc.	Basin Water Lower Limit of Detection	Basin Water Conc.	Blowdown Lower Limit of Detection	Blowdown Conc.	Other Sample	Other Lower Limit of Detection	Other Conc.
17	21 May 76	a	1.2×10^5	$>>5\times10^6$	6×10^4	B.D.L.	6×10^4	B.D.L.			
17	Aug 76	a	1×10^5	B.D.L.			1×10^5	B.D.L.			
		b	1×10^5	B.D.L.			1×10^5	B.D.L.			
18	21 May 76	a	1.2×10^5	B.D.L.	1.2×10^5	B.D.L.					

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*Concentrations are listed as fibers/liter for bulk water samples (no postscript). In cases where the bulk samples contained appreciable amounts of suspended solids, the samples were shaken, allowed to stand 4 hours, and the supernatant analyzed by electron microscopy; results are listed in fibers/liter (sup). The sediment was analyzed either by electron microscopy or light microscopy (LM); the results of sediment analysis by electron microscopy are listed as μg/g (sed), and by light microscopy as a percent of the sediment mass by weight. Concentrations (Conc.) below detection limits are indicated by B.D.L. Except as otherwise noted, all asbestos was identified as chrysotile.

+Replicates taken at a given sampling date.

[a] Site 7 has four natural-draft towers. For basin-water analyses, two samples were taken from each of the four tower basins. The lower limit of detection range from 6.3×10^4 to 3.0×10^5 for all eight samples.

[b] The lower limit of detection is relatively high due to high salt content in the water.

[c] Blowdown samples are from four separate mechanical-draft towers, one of which contains redwood fill.

[d] Chrysotile was found by light microscopy in the sediment suspended in the bulk water sample. Fibers were 2-5 μm in diameter, 60-130 μm in length, in small bundles.

Table V-14

RESULTS OF SCREENING PROGRAM FOR ONCE-THROUGH COOLING WATER SYSTEMS

(parts per billion)

	Plant #2512		Plant #3805		Plant #1720	
Compounds	Intake	Discharge	Intake	Discharge	Intake	Discharge
Antimony	<5	10	<5	<5	7	<5
Arsenic	6	70	<5	<5	18	25
Beryllium	<5	<5	<5	<5	<5	<5
Cadmium	<10	30	<5	<5	<5	<5
Chromium	<5	8	39	<5	24	17
Copper	22	24	6	5	16	20
Cyanide	<20	<20	<20	<20	20	20
Lead	<5	<5	19	<5	8	14
Mercury	0.21	0.17	0.23	0.32	0.42	0.42
Nickel	7	25	<5	<5	29	26
Selenium	35	58	11	<5	20	18
Silver	<5	<5	12	<5	<5	<5
Thallium	<5	13	<5	<5	<5	<5
Zinc	<5	<5	<5	<5	42	26
Phenol	100	100	<10	<10	30	50

Table V-15

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
2718	Zinc	340	-----
	Total Dissolved Solids	230,000	380,000
	Total Suspended Solids	3,000	4,000
	Total Organic Carbon	11,000	17,000
	Total Residual Chlorine	D < 10	20/20/20/20
	1,1,2,2-Tetrachloroethane	5	5
1716	Total Dissolved Solids	250,000	360,000
	Total Suspended Solids	7,000	10,000
	Total Organic Carbon	34,000	15,000
	Phenolics, 4AAP	12	7
	Total Residual Chlorine	D < 10	400/7100/5100/D<10
3414	2,4-Dichlorophenol	ND	4/8
	Total Dissolved Solids	23,000,000	24,000,000
	Total Suspended Solids	16,000	8,000
	Total Organic Carbon	25,000	26,000
	Phenolics, 4AAP	15	7
	Total Residual Chlorine	D < 10	250/320/310/280
4826	1,2-Dichlorobenzene	ND	30
	Total Dissolved Solids	12,200,000	12,300,000
	Total Suspended Solids	17,000	21,000
	Total Organic Carbon	12,000	30,000
	Phenolics, 4AAP	8	18
	Total Residual Chlorine	D < 10	1200/2000/1900/800
	1,2 or 1,3 or 1,4 Dichlorobenzene	18	-----

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb) Intake	Concentration (ppb) Discharge
1245	Total Dissolved Solids	35,000,000	33,000,000
	Total Suspended Solids	6,000	14,000
	Total Organic Carbon	14,000	25,000
	Phenolics, 4AAP	D < 5	D < 5
	Total Residual Chlorine	D < 10	D<10/200/120
1002	Bromoform	-----	31
	Chlorodibromomethane	-----	2.6
	Bis(2-Ethylhexyl) Pthalate	420	-----
	BHC(Lindane)-Gamma	-----	D < 0.1
	Antimony, Total	16	14
	Cadmium, Total	17	16
	Chromium, Total	13	14
	Copper, Total	22	24
	Lead, Total	10	11
	Mercury, Total	ND	1
	Nickel, Total	120	120
	Silver, Total	30	36
	Zinc, Total	32	24
	Total Dissolved Solids	11,488,000	13,437,000
	Total Suspended Solids	38,400	49,800
	Total Organic Carbon	8,150	7,930
	Total Residual Chlorine	0/0/200/300/400/540/900	800/310/200/250/170/150/150
	Free Residual Chlorine	200/1000/700/500/700/300/500	500/600/180/200/250/170/150/150
	Iron, Total	600	760

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1742	Cadmium, Total (Dissolved)	40(5)	-----
	Chromium, Total (Dissolved)	24/20(ND/30)*	-----
	Copper, Total (Dissolved)	21/20(ND/9)*	-----
	Lead, Total (Dissolved)	9/ND<20(ND/90)*	-----
	Nickel, Total (Dissolved)	17/ND<5(ND/40)*	-----
	Silver, Total (Dissolved)	(ND/10)*	-----
	Zinc, Total (Dissolved)	ND/70(30/ND<60)*	-----
	Total Dissolved Solids	340,000	1,200,000
	Total Suspended Solids	100,000	90,000
	Total Organic Carbon	10,000	9,000
	Aluminum, Total	2,000	-----
	Barium, Total (Dissolved)	60(30)	-----
	Boron, Total (Dissolved)	90(200)	-----
	Calcium, Total (Dissolved)	51,000(44,000)	-----
	Cobalt, Total	10	-----
	Manganese Total	200	-----
	Magnesium, Total (Dissolved)	23,000(22,000)	-----
	Molybdenum, Total	9	-----
	Phenolics, 4AAP	6	260
	Total Residual Chlorine	-----	330/890/800/860
	Sodium, Total (Dissolved)	21,000(20,000)	-----
	Tin, Total	30	-----
	Titanium, Total	40	-----
	Iron, Total	4,000	-----
	Vanadium, Total (Dissolved)	ND/ND<10(ND/20)*	-----

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)		
		Intake	Discharge	
			Chlorinated	Dechlorinated
2608	Benzene	-----	30/70/100/50/ND/1000	D<10/D<10/D<10/40/D<10/D<10 D<10/130/D<10
	2-Chloronaphthalene	ND	D<10/ND	ND
	Chloroform	-----	D<8/10/D<10/D<9/D<8/D<8	D<6/4/D<10/D<5/D<10/D<6.5 D<6/D<3/10
	1,1-Dichloroethylene	-----	ND/10/ND/40/ND/D<10	ND/ND/ND/D<10/ND/ND/ND/ND/ND
	Ethylbenzene	-----	ND/ND/ND/ND/ND/D<10	ND/ND/D<10/D<10/ND/ND/ND/D<10/ND
	Methylene Chloride	-----	210/350/10/100/ND/370	106/190/240/40/100/20/20/140/50
	Bromoform	-----	ND/ND/ND/ND/ND/ND	ND/ND/D<10/ND/ND/ND/ND/ND/ND
	Phenol (GC/MS)	ND/26*	ND/17*	ND/11*
	Butyl Benzyl Phthalate	ND	120	ND
	Di-N-Butyl Phthalate	D < 10	10	D < 10
	Toluene	-----	ND/ND/ND/ND/ND/D<10	ND/ND/D<10/D<10/ND/ND/ND D<10/ND
	Trichloroethylene	-----	D<10/D<10/D<10/ND/D<10/ND	ND/ND/ND/ND/ND/D<10/ND/ND/ND
	Antimony, Total	7	3	5
	Arsenic, Total	3	3	6
	Chromium, Total	13	13	12
	Copper, Total	7	9	11
	Mercury, Total	1.2	0.7	ND < 0.1
	Selenium, Total	ND < 2	3	ND < 2
	Zinc, Total	ND < 60	ND < 60	64
	Total Dissolved Solids	229,000	225,000	222,000
	Total Organic Carbon	6,000	6,000	6,000
	Barium, Total	10	13	11
	Calcium, Total	39,600	42,200	42,200
	Manganese, Total	53	71	59

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)		
		Intake	Discharge	
			Chlorinated	Dechlorinated
2608	Magnesium, Total	13,100	13,000	13,000
(Cont)	Total Resdual Chlorine	-----	0/40/40/40	0/0/0/0
	Sodium, Total	D<15,000	15,000	23,000
	Iron, Total	248		
2603	Benzene	D < 10	D < 10	D < 10
	1,1,1-Trichloroethane	ND	ND	D < 10
	Chloroform	D < 10	D < 10	D < 10
	1,1-Dichloroethylene	ND	ND	D < 10
	Ethylbenzene	ND	ND	D < 10
	Methylene Chloride	D < 10	20	35
	Pentachlorophenol	ND	D < 10	ND
	Phenol (GC/MS)	ND/9*	4/ND*	4/D < 10*
	Bis(2-ethylhexyl) Phthalate	D < 10	D < 10	D < 10
	Butyl Benzyl Phthalate	D < 10	ND	ND
	Di-N-Butyl Phthalate	D < 10	20	D < 10
	Diethyl Phthalate	50	20	D < 10
	Tetrachlete ethylene	D < 10	D < 10	D < 10
	Trichloroethylene	D < 10	D < 10	D < 10
	Arsenic, Total	ND < 2	ND < 2	3
	Chromium, Total	10	13	11
	Copper, Total	22	23	22
	Mercury, Total	0.2	0.1	0.1
	Nickel, Total	8	ND < 5	ND < 5
	Silver, Total	ND < 1	ND < 1	2
	Zinc, Total	88	68	ND < 60
	Total Dissolved Solids	292,000	271,000	247,000
	Total Organic Carbon	9,000	6,000	6,000

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb) Intake	Discharge Chlorinated	Dechlorinated
2603	Aluminum, Total	497	445	689
(Cont)	Barium, Total	17	-----	-----
	Boron, Total	ND < 50	140	53
	Calcium, Total	48,700	45,300	44,900
	Manganese, Total	65	61	65
	Magnesium, Total	15,300	13,900	14,000
	Total Residual Chlorine	-----	D<30/200/240/270/300	D<30/D<30/D<30/110/D<30
	Sodium, Total	23,600	20,700	18,300
	Tin, Total	36	ND < 5	ND < 5
	Titanium, Total	18	ND < 15	20
	Iron, Total	842	715	921
	Free Residual Chlorine	-----	40/140/10	-----
2607	Benzene	20	D < 10	20
	Chloroform	ND	D < 10	ND
	1,1-Dichloroethylene	10	ND	ND
	Methylene Chloride	ND	10	10
	Phenol (GC/MS)	ND/D<10*	ND/D<10*	ND/D<10*
	Bis(2-ethylhexyl) Phthalate	D < 10	D < 10	D < 10
	Di-N-Butyl Phthalate	D < 10	ND	D < 10
	Toluene	D < 10	ND	D < 10
	Trichloroethylene	ND	D < 10	ND
	Arsenic, Total	5	5	4
	Chromium, Total	7	10	7
	Copper, Total	14	14	14

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)		
		Intake	Discharge	
			Chlorinated	Dechlorinated
2607	Selenium, Total	3.8	8.3	2.7
(Cont)	Thallium, Total	3	ND < 2	ND < 2
	Zinc, Total	ND < 60	ND < 60	73
	Total Dissolved Solids	260,000	263,000	294,000
	Total Organic Carbon	14,000	9,000	6,000
	Aluminum, Total	2,440	2,180	2,090
	Barium, Total	32	31	31
	Boron, Total	70	56	89
	Calcium, Total	44,800	35,400	43,400
	Manganese, Total	98	86	97
	Magnesium, Total	14,200	11,700	13,700
	Molybdenum, Total	ND < 5	10	ND < 5
	Total Residual Chlorine	-----	0/0/0/0/0/0	0/0/0/0/0/0
	Sodium, Total	20,500	15,500	19,800
	Titanium, Total	51	58	58
	Iron, Total	2,560	2,260	2,340
5513	Benzene	40	-----	-----
	Benzidene	ND	ND/30/40	ND
	1,1,1-Trichloroethane	ND	ND/D<10/ND	ND
	Chloroform	ND	ND/20/10	ND
	1,2-Dichlorobenzene	ND	ND/D<10	ND
	2,4-Dichlorophenol	ND	1/ND	ND
	Ethylbenzene	D < 10	ND	ND
	Methyl Chloride	50	400/50/50	10
	Bis(2-ethylhexyl) Phthalate	D < 10	ND	ND
	Di-N-Butyl Phthalate	D < 10	10	ND

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-15 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ONCE-THROUGH COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)		
		Intake	Discharge	
			Chlorinated	Dechlorinated
5513	Toluene	ND	ND/ND/D<10	ND
(Cont)	Trichloroethylene	ND	ND/ND/D<10	ND
	Antimony, Total	10	10	9
	Arsenic, Total	4	ND < 10	4
	Chromium, Total	19	25	24
	Copper, Total	8	11	10
	Cyanide, Total	10	ND < 5	ND < 5
	Lead, Total	ND < 20	34	41
	Mercury, Total	1	0.8	1.9
	Selenium, Total	3	ND < 2	3
	Silver, Total	ND < 1	3	ND < 1
	COD	35,000	33,000	33,000
	Total Dissolved Solids	545,000	526,000	506,000
	Total Suspended Solids	10,000	10,000	10,000
	Total Organic Carbon	13,000	14,000	14,000
	Aluminum, Total	283	245	289
	Barium, Total	24	18	21
	Boron, Total	83	51	50
	Calcium	84	73	76
	Cobalt, Total	D < 5	D < 5	D < 5
	Manganese, Total	66	63	62
	Magnesium, Total	33,000	30,200	30,900
	Molybdenum, Total	-----	16	14
	Phenolics, 4AAP	13	15	19
	Sodium, Total	49,000	35,000	39,700
	Tin, Total	30	ND < 5	ND < 5
	Titanium, Total	ND < 15	19	18
	Iron, Total	675	537	646
	Total Solids	612,000	-----	-----

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

The data in Table V-15 indicate that there were net increases in all of the following compounds: total dissolved solids, total suspended solids, total organic carbon, total residual chlorine, free available chlorine, 2,4-dichlorophenol, 1,2-dichlorobenzene, phenolics, chromium, copper, lead, mercury, silver, iron, arsenic, zinc, barium, calcium, manganese, sodium, methylene chloride, aluminum, boron and titanium. However, the net increase was greater than 10 ppb only for 1,2-dichlorobenzene, total phenolics, lead, zinc, and methylene chloride. Only for 1,2-dichlorobenzene and total phenolics were the increases greater than 25 ppb, and in one case an increase of slightly more then 250 ppb was observed for total phenolics.

Recirculating Cooling Water Systems

Four powerplants with cooling towers were sampled at intake and discharge points during the screening phase of the sampling program. The results of the priority pollutants analyses of these samples are presented for each plant in table V-16. The metal, organic (other than the volatile organics), and asbestos samples were 24-hour composites.

Eight powerplants with cooling towers were sampled at intake and discharge points during the verification sampling program. As noted in table V-2, plants using fresh, salt or brackish water included. The results of the verification sampling program for cooling tower blowdown are presented in table V-17.

The data presented in tables V-16 and V-17 indicate that there was a net increase from the influent concentration to the effluent concentration for the following compounds: trichlorofluoromethane, bromoform, chlorodibromomethane, bis(2-ethylhexyl) phthalate, antimony, arsenic, cadmium, chromium, mercury, nickel, selenium, silver, thallium, benzene, tetrachloroethylene, toluene, copper, cyanide, lead, zinc, chloroform, phenol, asbestos, total dissolved solids, total suspended solids, total organic carbon, total residual chlorine, 1,2-dichlorobenzene, 2,4-dichlorophenol, boron, calcium, magnesium, molybdenum, total phenolics, sodium, tin, vanadium, cobalt, iron, chloride, 2,4,6-trichlorophenol, and pentachlorophenol. It must be recognized, however, that recirculating cooling systems tend to concentrate the dissolved solids present in the make-up water and, thus, a blowdown stream with many different compounds showing concentration increases is to be expected. Of the priority pollutants detected as net discharges, the concentration increase was greater than 10 ppb only for bis(2-ethylhexyl) phthalate, cadmium, chromium, nickel, selenium, silver, toluene, copper, cyanide, lead, zinc, phenol, 1,2-dichlorobenzene, total phenolics, and 2,4,6,-trichlorophenol. Net increases of greater than 25 ppb were observed for all of the following: bis (2-ethylhexyl) phthalate, cadmium, chromium, nickel, selenium, silver, toluene, copper, cyanide, lead, zinc, 1,2-dichlorobenzene, and 2,4,6-trichlorophenol. The net concentration increase exceeded 100 ppb only for bis (2-ethylhexyl) phthalate, cadmium, chromium, copper, cyanide, lead, and zinc.

Table V-16

RESULTS OF THE SCREENING PHASE OF THE SAMPLING PROGRAM FOR COOLING TOWER BLOWDOWN

Plant 3404

Pollutant	Concentration (ppb)	
	Intake	Discharge
Benzene	1	1
Chloroform	3/1	1/1
1,4-Dichlorobenzene	ND < 1	1
1,1-Dichloroethylene	1/1	2/ND<1
Methylene Chloride	20/1	10/4
Trichlorofluoromethane	ND < 1	1
Bromoform	ND<1/ND<1	4/4
Chlorodibromomethane	ND<1/ND<1	3/3
Phenol	ND<1/36	1/<10
Bis(2-Ethylhexyl) Phthalate	11	62
Di-N-Butyl Phthalate	4	ND < 1
Toluene	3/3	6/2
Antimony, Total	11	14
Arsenic, Total	<5	8
Cadmium, Total	15	40
Chromium, Total	16	23
Copper, Total	25	13
Lead, Total	5	<5
Mercury, Total	0.34	0.58
Nickel, Total	21	29
Selenium, Total	55	87
Silver, Total	40	64
Thallium, Total	<5	9

Table V-16 (Continued)

RESULTS OF THE SCREENING PHASE OF THE SAMPLING PROGRAM FOR COOLING TOWER BLOWDOWN

Plant 0631

Pollutant	Concentration (ppb)	
	Intake	Discharge
Methylene Chloride	20.6	15.0
Phenol	39/20	34/40
Toluene	24.4	21
Benzene	ND < 1	1.5
Chloroform	5.7	ND < 1
Tetrachloroethylene	ND < 1	1
Toluene	47.8	115
Antimony, Total	<5	6
Arsenic, Total	<5	13
Cadmium, Total	10	25
Chromium, Total	37	75
Copper, Total	25	150
Cyanide, Total	130	360
Lead, Total	<5	17
Mercury, Total	0.41	0.91
Nickel, Total	8	100
Selenium, Total	<5	23
Silver, Total	9	32
Zinc, Total	41	67

Table V-16 (Continued)

RESULTS OF THE SCREENING PHASE OF THE SAMPLING PROGRAM FOR COOLING TOWER BLOWDOWN

Plant 2414

Pollutant	Concentration (ppb)	
	Intake	Discharge
Benzene	2/1.3	2/1
1,2-Dichloroethane	2	ND < 1
1,1,1-Trichloroethane	1	ND < 1
Chloroform	2	3
1,4-Dichlorobenzene	1	ND <1
Methylene Chloride	2/1	3/ND<1
Phenol	10	25
Bis(2-Ethylhexyl) Phthalate	105	262
Diethyl Phthalate	5	ND < 1
Toluene	1/1	7/10
Cis 1,2-Dichloroethylene	10/15	20/ND<1
Ethylbenzene	1	1
Antimony, Total	<5	7
Arsenic, Total	5	9
Asbestos (fibers/liter)	28,400	147,000
Chromium, Total	<5	11
Copper, Total	21	70
Cyanide, Total	<20	50
Lead, Total	7	8
Mercury, Total	0.88	1.02
Nickel, Total	8	58
Selenium, Total	15	22
Silver, Total	45	65
Thallium, Total	6	5

Table V-16 (Continued)

RESULTS OF THE SCREENING PHASE OF THE SAMPLING PROGRAM FOR COOLING TOWER BLOWDOWN

Plant 4836

Pollutant	Concentration (ppb)	
	Intake	Discharge
Chloroform	9/6	ND<1/1
1,1-Dichloroethylene	ND<1/1	1/1
Methylene Chloride	49/8	4/4
Bromoform	1	ND < 1
Trichlorofluoromethane	ND < 1	1
Chlorodibromoform	1/1	ND<1/ND<1
Phenol	3	1
Bis(2-Ethylhexyl) Phthalate	ND < 1	1
Di-N-Butyl Phthalate	1	ND < 1
Diethyl Phthalate	2	ND < 1
Tetrachloroethylene	1/2	ND<1/ND<1
Toluene	6/3	3/3
1,4-Dichlorobenzene	1	ND < 1
Bromodichloroethylene	2	ND < 1
Antimony, Total	<5	10
Chromium, Total	6	11
Copper, Total	8	95
Cyanide, Total	62	75
Mercury, Total	0.15	0.29
Nickel, Total	6	10
Selenium, Total	<5	8
Zinc, Total	23	19

Table V-17

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
2718	2,4-Dichlorophenol	3	ND
	Pentachlorophenol	4	ND
	Cadmium, Total	8	4
	Chromium, Total	ND/400*	ND/300*
	Copper, Total	14/10	53/20
	Lead, Total	ND < 20	40
	Nickel, Total	ND/200*	ND/124*
	Thallium, Total	20	20
	Total Dissolved Solids	370,000	27,000,000
	Total Suspended Solids	2,000	17,000
	Total Organic Carbon	9,000	46,000
	Barium, Total	100	100
	Boron, Total	80	ND < 50
	Calcium, Total	59,000	35,000
	Cobalt, Total	10	10
	Manganese, Total	60	60
	Magnesium, Total	33,000	20,000
	Molybdenum, Total	20	20
	Phenolics, 4AAP	-----	ND < 5
	Total Residual Chlorine	ND < 10	350/280/90/10
	Sodium, Total	ND < 15,000	ND < 15,000
	Tin, Total	30	30
	Titanium	20	20
	Iron, Total	2,000	1,000
	1,1,2,2-Tetrachloroethane	ND < 5	-----

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1245	1,2-Dichlorobenzene	ND	26
	2,4-Dichlorophenol	3	8
	Pentachlorophenol	-----	4
	Cadmium, Total	ND < 2	5
	Chromium, Total	83/20*	55/40*
	Copper, Total (Dissolved)	12/ND<6*	70/30*
	Nickel, Total	ND/ND<5*	ND/10*
	Silver, Total	ND < 1	2
	Total Dissolved Solids	900,000	2,240,000
	Total Suspended Solids	2,000	4,000
	Total Organic Carbon	22,000	76,000
	Boron, Total	500	2,000
	Calcium, Total	53,000	140,000
	Manganese, Total	8	ND < 3
	Magnesium, Total	22,000	48,000
	Molybdenum, Total	ND < 5	40
	Phenolics, 4AAP	7	20
	Total Residual Chlorine	1,170	0/0/0/0/0
	Sodium, Total	170,000	350,000
	Tin, Total	ND < 5	30
	Vanadium, Total	ND < 3	10

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1226	Chloroform	-----	D < 1
	Bromoform	-----	154
	Dichlorobromomethane	-----	8.2
	Chlorodibromomethane	-----	58.5
	Antimony, Total	ND/7*	7
	Arsenic, Total	ND/3*	ND/4*
	Cadmium, Total	2.1/ND<2*	1.8/ND<2*
	Chromium, Total	ND/7/7*	28/5/20*
	Copper, Total (Dissolved)	10/12/10*(10)	47/50*
	Lead, Total (Dissolved)	12/10/ND<20*(7/ND/20)*	3/ND<20*
	Mercury, Total	ND<1/0.5*	0.2
	Nickel, Total (Dissolved)	27/1.5/ND<5*(29/ND*)	6/6/ND<5*
	Silver, Total	ND/1.3/ND<1*	0.7/ND<1*
	Zinc, Total (Dissolved)	ND/9/70*(50/ND<60)*	50/26/ND<60*
	Total Dissolved Solids	190,000	1,050,000
	Total Suspended Solids	14,000	8,000
	Total Organic Carbon	10,000	11,000
	Aluminum, Total (Dissolved)	700(100)	400
	Barium, Total (Dissolved)	20(20)	20
	Boron, Total	ND < 50	60
	Calcium, Total (Dissolved)	6,900(D<5000)	6,900
	Cobalt, Total	7	8
	Manganese, Total (Dissolved)	200(200)	100
	Magnesium, Total (Dissolved)	4,500(5000)	4,900
	Phenolics, 4AAP	12	8
	Total Residual Chlorine	ND	D<10/D<10/D<10/D<10/D<10/D<10/90/D<10
	Sodium, Total (Dissolved)	33,000(36,000)	210,000

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1226 (Cont'd)	Titanium, Total	20	20
	Iron, Total (Dissolved)	2,000(1,000)	3,000
	Vanadium, Total	ND/40/ND<10*	27/ND<10
	Lead (Dissolved)	(7/ND<20*)	-----
4251	1,2-Dichlorobenzene	ND	20
	2,4-Dichlorophenol	11	ND
	Cadmium, Total	9	ND < 2
	Chromium, Total	42/500*	10/10*
	Copper, Total	55/20*	81/40*
	Lead, Total	30	ND < 20
	Nickel, Total	24/200*	42/10*
	Zinc, Total	340/ND<60*	40/ND<60*
	Total Dissolved Solids	227,000	430,000
	Total Suspended Solids	10,000	53,000
	Total Organic Carbon	34,000	15,000
	Barium, Total	40	-----
	Boron, Total	60	70
	Calcium, Total	29,000	ND/53,000*
	Cobalt, Total	10	ND < 5
	Manganese, Total	200	70
	Magnesium, Total	7,600	8,900
	Molybdenum, Total	20	ND < 5
	Phenolics, 4AAP	16	8
	Total Residual Chlorine	D < 10	100/4100/6500/6200/5200/4300/3950/3400/2800/2500/2000/1550/1300/750
	Sodium, Total	17,000	52,000
	Iron, Total	2,000	300

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
3404	1,2-Dichlorobenzene	18	ND
	2,4-Dichlorophenol	12	8
	Pentachlorophenol	12	4
	Cadmium, Total	100	200
	Chromium, Total	78/800*	110/1000*
	Copper, Total	33/ND<60*	24/60
	Lead, Total	500	800
	Nickel, Total	34/100*	78/200*
	Silver, Total	40	80
	Total Dissolved Solids	26,000,000	34,000,000
	Total Suspended Solids	110,000	90,000
	Total Organic Carbon	26,000	9,000
	Aluminum, Total	2,000	2,000
	Boron, Total	4,000	4,000
	Calcium, Total	340,000	460,000
	Cobalt, Total	ND < 50	80
	Manganese, Total	200	100
	Molybdenum, Total	80	100
	Phenolics, 4AAP	5	-----
	Total Residual Chlorine	ND<10/ND<10/ND<10/ND<10	230/190/390/170
	Sodium, Total	6,000,000	7,000,000
	Tin, Total	300	500
	Titanium, Total	200	200
	Iron, Total	4,000	4,000
	Vanadium, Total	200	200

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
5409	Benzene	2.4	1.5
	Carbon Tetrachloride	D < 1	-----
	Chloroform	1.4	2.4
	1,2-Dichlorobenzene	5.3	-----
	Dichlorobromomethane	-----	2.6
	Chlorodibromomethane	-----	D < 1
	Toluene	2	-----
	Trichloroethylene	4	4
	Cadmium, Total	1.4	1
	Chromium, Total	ND < 2	37
	Copper, Total (Dissolved)	27	3,800(620)
	Cyanide, Total	15,000	5
	Lead, Total (Dissolved)	8	130(70)
	Mercury, Total	ND < 0.2	1
	Nickel, Total	1.7	4
	Selenium, Total	2	ND < 2
	Silver, Total	1.6	14
	Thallium, Total	ND < 1	8
	Zinc, Total (Dissolved)	15	290(61)
	Total Suspended Solids	5	460,000
	Total Organic Carbon	20,000	21,000
	Chloride	-----	110,000
	Vanadium, Total	13	17
	1,3 and 1,4-Dichlorobenzene	2.4	-----

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
5604	Benzene	1.2	D < 1
	Toluene	9.1	23.5
	Antimony, Total	4	5
	Arsenic, Total	ND < 1	7
	Chromium, Total	ND < 2	2
	Copper, Total	700	180
	Cyanide, Total	4	3
	Lead, Total	6	ND < 3
	Nickel, Total	ND < 0.5	6
	Selenium, Total	2	ND < 2
	Silver, Total	ND < 3	3
	Zinc, Total	53	780
	Total Suspended Solids	------	42,000
	Total Organic Carbon	5,500	14,000
	Chloride	14,000	54,000
	Vanadium, Total	11	24

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-17 (Continued)

SUMMARY OF RESULTS OF VERIFICATION PROGRAM FOR RECIRCULATING COOLING WATER SYSTEMS

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
.4602	2,4,6-Trichlorophenol	ND	35
	Pentachlorophenol	ND	4
	Cadmium, Total	ND < 20	5
	Chromium, Total	73/100*	130/400*
	Copper, Total	21/50*	62/400*
	Lead, Total	30	ND < 30
	Nickel, Total	98/ND<5*	60/200*
	Silver, Total	2	ND < 1
	Zinc, Total	ND/70*	210/200*
	Total Dissolved Solids	190,000	880,000
	Total Suspended Solids	2,000	2,000
	Total Organic Carbon	D < 1000	9,000
	Barium, Total	300	200
	Boron, Total	300	60
	Calcium, Total	260,000	110,000
	Cobalt, Total	8	10
	Manganese, Total	90	50
	Magnesium, Total	100,000	57,000
	Molybdenum, Total	20	60
	Phenolics, 4AAP	D < 5	D < 5
	Total Residual Chlorine	D < 10	7340/4730/190/50
	Sodium, Total	95,000	33,000
	Tin, Total	60	60
	Titanium, Total	30	ND < 20
	Iron, Total	1,000	2,000
	Vanadium, Total	20	20

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Additional Data Sources

Another source of useful data is a study on the chlorination of a fresh water once-through cooling system that found that chloroform levels in the outlet from the condenser during periods of chlorine addition ranged between 1.4 and 8.7 ppb (47). The mean chloroform concentration in the condenser outlet during chlorination was 5.0 ppb. The intake in this same study had chloroform levels consistently below 1.0 ppb with the exception of one sample point at 1.2 ppb.

Samples were also analyzed for dichlorobromomethane in this same study (47). Condenser outlet dichlorobromomethane levels ranged from 0.9 to 4.6 ppb during the period of chlorine addition. The mean dichlorobromomethane level was 2.0 ppb. Intake water had dichloromethane levels consistently below 0.2 ppb.

Analysis was also done for dibromochloromethane (47). Condenser outlet dibromochloromethane levels ranged from less than 0.2 ppb to 1.5 ppb during the period of chlorine addition. The mean dibromochloromethane level was 0.77 ppb but in three samples the level of dibromochloromethane could not be quantified; these samples were not used in calculating the mean. Intake water was consistently below 0.2 ppb dibromochloromethane.

Summary of the Results of Cooling Water Sampling and Data Collecting Efforts

An examination of all the available data, including screening, verification, surveillance and analysis, and literature data, leads to several major conclusions. First, net discharges of metals other than chromium and zinc are the result of corrosion of metal surfaces within the cooling water system. Net discharges from once-through systems are typically less than 20 ppb. Net discharges from recirculating cooling systems may be higher because of the concentrating effect these systems have on dissolved solids. Net discharges of chromium and zinc from recirculating systems may be as high as 1,000 ppb zinc and 200 ppb chromium as the result of the use of corrosion control additives(13).

Second, the organic pollutants that were detected in the sampling efforts may result from several sources. Methylene chloride may be a product of chlorination or, since it is a common lab solvent, may be an analytical error. Bis (2-ethylhexyl) phthalate is probably the result of the loss of plasticizers from plastic sampling tubes or bottles. 2,4-dichlorophenol, 1,2-dichlorobenzene, bromoform, chlorodibromomethane, and chloroform all may result from cooling water chlorination. Net discharges of these compounds were always at or below 30 ppb, often only a few ppb. The concentration scale up effect of recirculating cooling systems may account for increases in some of the organics. The use of non-oxidizing biocides may explain the presence of compounds like phenol, benzene, toluene, 1,2-dichlorobenzene, 2,4,6-trichlorophenol and pentachlorophenol (13,17).

A third major finding was a net dscharge of asbestos in the cooling tower blowdown of plant 2414. Since asbestos was also present in the make-up water, it is not clear whether fill erosion is occuring. The introduction of asbestos into cooling tower blowdown from fill erosion has already been demonstrated by the data presented in table V-13.

Finally, net discharges of total residual chlorine were observed in both once-through and recirculating systems. Net discharges as high as 7,100 pph were observed.

ASH HANDLING

Steam electric powerplants using oil or coal as a fuel produce ash as a waste product of combustion. The total ash product is the combination of bottom ash and fly ash. Bottom ash is the residue which accumulates on the furnace bottom, and fly ash is the lighter material which is carried over in the flue gas stream. In coal-burning boilers, some of the fly ash or carryover ash settles in the economizer section of the boiler. This ash is called economizer ash and is typically the larger particles of the fly ash.

The ash composition of oil, on a weight percent basis, is much lower than that of coal. Oil ash seldom exceeds 0.2 percent whereas coal ash comprises from 3 to 30 percent of the coal. As such, the presence of ash is an extremely important consideration in the design of a coal-fired boiler and, to a lesser extent, an oil-fired boiler. Improper design could lead to accumulation of ash deposits on furnace walls and tubes, leading to reduced heat transfer, increased pressure drop, and corrosion.

Ash handling or transport is the conveyance of the accumulated waste products to a disposal system. The method of conveyance may be either wet (sluicing) or dry (pneumatic). Dry handling systems are more typical for fly ash than bottom ash. The method of disposal for a dry ash is commonly by landfill but the ash can also be sold as a by-product for a variety of uses such as an ingredient for road pavement or for portland cement (alkaline ashes). Ash from oil-fired units is often sold for the recovery of vanadium.

Wet ash handling systems produce wastewaters which are currently either discharged as blowdown from recycle systems or discharged directly to receiving streams in a once-through manner. Statistical analyses of fly ash and bottom ash wastewater flow rates reported in 308 responses from the industry are presented in tables V-18 and V-19. The chemical characteristics of ash handling wastewater are basically a function of the inlet or makeup water, composition of the fuel burned, and the composition of other wastewaters discharged into the ash settling ponds. These characteristics are discussed in this section.

Table V-18

FLY ASH POND OVERFLOW
(308 Questionnaire)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: Coal*						
Flow:	GPD/plant	167	2,610,724.6	3,397,528.7	0.00	23,000,000
	GPD/MW	166	3,807.976	3,608.152	0.00	16,386.91
Fuel: Gas*						
Flow:	GPD/plant	21	322,170.0	764,538.7	0.00	3,250,000
	GPD/MW	21	1,899.28	3,026.676	0.00	11,535,049
Flow: Oil*						
Flow:	GPD/plant	47	487,996.2	1,607,619.2	0.00	9,750,000
	GPD/MW	47	828.552	1,652.856	0.00	7,485.76

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Table V-19

BOTTOM ASH POND OVERFLOW
(308 Questionnaire)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: Coal*						
Flow:	GPD/plant	219	2,600,998.7	5,072,587.5	0.00	33,600,000
	GPD/MW	218	3,880.983	5,147.284	0.00	38,333.33
Fuel: Gas*						
Flow:	GPD/plant	25	417,345.2	1,026,066.7	0.00	4,020,000
	GPD/MW	25	1,804.65	3,229.089	0.00	11,535.049
Flow: Oil*						
Flow:	GPD/plant	40	322,913.6	907,839.3	0.00	4,900,000
	GPD/MW	40	622.696	1,698.706	0.00	9,902.53

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Fly Ash From Oil-Fired Plants

The ash from fuel oil combustion usually is in the form of fly ash. The relatively small quantity of ash (compared to coal) is capable of causing severe problems of external deposits and corrosion in boilers. The many elements which may appear in oil ash deposits include vanadium, sodium, and sulfur. Compounds containing these elements are found in almost every deposit in boilers fired by residual fuel oil and often constitute the major portion of these deposits.

Origin of Crude Oil Ash

Some of the ash-forming constituents in the crude oil had their origin in animal and vegetable matter from which the oil was derived. The remainder is extraneous material resulting from contact of the crude oil with rock structures and salt brines or picked up during refining processes, storage, and transportation.

In general, the ash content increases with increasing asphaltic constituents in which the sulfur acts largely as a bridge between aromatic rings. Elemental sulfur and hydrogen sulfide have been identified in crude oil. Simpler sulfur compounds, including thioesters, disulfides, thiophenes, and mercaptans, are found in the distillates of crude oil.

Vanadium, iron, sodium, nickel, and calcium in fuel oil are common in rock strata, but elements including vanadium, nickel, zinc, and copper are believed to come from organic matter from which the petroleum was created. Vanadium and nickel are known to be present in organometallic compounds known as porphyrins which are characteristic of certain forms of animal life. Table V-20 summarizes the amounts of vanadium, nickel, and sodium present in residual fuel oils from various crudes.

Crude oil, as such, is not normally used as a fuel but is further processed to yield a wide range of more valuable products. For example, in a modern United States refinery, the average product yield, as a percentage of total throughput, is given in table V-21. Virtually all metallic compounds and a large part of the sulfur compounds are concentrated in the distillation residue, as illustrated for sulfur in table V-22. Where low-sulfur residual fuel oils are required, the oil is obtained by blending with suitable stocks, including both heavy distillates and distillation from low-sulfur crudes. This procedure is used occasionally if a residual fuel oil must meet specifications such as vanadium, or ash content.

Release of Ash During Combustion

Residual fuel oil is preheated and atomized to provide enough reactive surface to burn completely within the boiler furnace. The atomized fuel oil burns in two stages. In the first stage, the volatile portion burns and leaves a porous coke residue; and, in the second stage, the coke residue burns. In general, the rate of combustion of

Table V-20

VANADIUM, NICKEL, AND SODIUM CONTENT OF RESIDUAL FUEL OIL (18)

(parts per million by weight)

Source of Crude Oil	Vanadium	Nickel	Sodium
Africa			
1	5.5	5	22
2	1	5	--
Middle East			
3	7	--	1
4	173	51	--
5	47	10	8
United States			
6	13	--	350
7	6	2.5	120
8	11	--	84
Venezuela			
9	--	6	480
10	57	13	72
11	380	60	70
12	113	32	49
13	93	--	38

Table V-21

AVERAGE PRODUCT YIELD OF A MODERN UNITED STATES REFINERY (18)

Product	Percentage of Total Throughput
Gasoline	44.4
Lube oil fraction	16.4
Jet fuel	6.2
Kerosine	2.9
Distillates	22.5
Residual fuel	7.6

Table V-22

SULFUR CONTENT IN FRACTIONS OF KUWAIT CRUDE OIL (18)

Fraction	Distillation Range (°F)	Total Sulfur (% by Weight)
Crude Oil	--	2.55
Gasoline	124-253	0.05
Light naphtha	257-300	0.05
Heavy naphtha	307-387	0.11
Kerosene	405-460	0.45
Light gas oil	477-516	0.85
Heavy gas oil	538-583	1.15
Residual oil	588-928	3.70

the coke residue is inversely proportional to the square of its diameter, which, in turn, is related to the droplet diameter. Thus, small fuel droplets give rise to coke residues which burn very rapidly, and the ash-forming constituents are exposed to the highest temperatures in the flame envelope. The ash-forming droplets are heated more slowly, partly in association with carbon. Release of the ash from these residues is determined by the rate of oxidation of the carbon (18).

During combustion, the organic vanadium compounds in the residual fuel oil thermally decompose and oxidize in the gas stream to V_2O_3, V_2O_4 and finally V_2O_5. Although complete oxidation may not occur and there may be some dissociation, a large part of the vanadium originally present in the oil exists as vapor phase V_2O_5 in the flue gas. The sodium, usually present as a chloride in the oil, vaporizes and reacts with sulfur oxides either in the gas stream or after deposition on tube surfaces. Subsequently, reactions take place between the vanadium and sodium compounds with the formation of complex vanadates which have melting points lower than those of the parent compounds. An example is shown in equation 9. The melting point of each compound is given below as well as the formula for the compound.

$$\underset{(1625\ F)}{Na_2SO_4} + \underset{(1275\ F)}{V_2O_5} \rightleftarrows \underset{(1165\ F)}{2NaVO_3} + SO_3 \qquad (9)$$

Excess vanadium or sodium in the ash deposit, above that necessary for the formation of the sodium vanadates (or vanadyl vanadates), may be present as V_2O_5 and Na_2SO_4, respectively (18).

The sulfur in residual fuel is progressively released during combustion and is promptly oxidized to sulfur dioxide (SO_2). A small amount of sulfur dioxide is further oxidized to SO_3 by a small amount of atomic oxygen present in the hottest part of the flame. Also, catalytic oxidation of SO_2 to SO_3 may occur as the flue gases pass over vanadium rich ash deposits on high-temperature superheater tubes and refractories (18).

Characteristics of Fuel Oil Ash

With respect to fuel oil ash characteristics, sodium and vanadium are the most significant elements in fuel oil because they can form complex compounds having low melting temperatures, 480 to 1250 F, as shown in table V-23. Such temperatures fall within the range of tube-metal temperatures generally encountered in furnace and superheater tube banks of many oil-fired boilers. Because of its complex chemical composition, fuel-oil ash seldom has a single sharp melting point, but rather softens and melts over a wide temperature range (18). Oil ash (especially from plants using Venezuelan and certain Middle Eastern oil) can contain significant amounts of nickel.

Table V-23

MELTING POINTS OF SOME OIL/ASH CONSTITUENTS (18)

Compound	Melting Point (°F)
Aluminum oxide, Al_2O_3	3720
Aluminimu sulfate, $Al_2(SO_4)_3$	1420*
Calcium oxide, CaO	4662
Calcium sulfate, $CaSO_4$	2640
Ferric oxide, Fe_2O_3	2850
Ferric sulfate, $Fe_x(SO_y)_3$	895
Nickel oxide, NiO	3795
Nickel sulfate, $NiSO_4$	1545*
Silicon dioxide, SiO_2	3130
Sodium sulfate, Na_2SO_4	1625
Sodium bisulfate, $NaHSO_4$	480*
Sodium pyrosulfate, $Na_2S_2O_7$	750*
Sodium ferric sulfate, $Na_3Fe(SO_4)_3$	1000
Vanadium trioxide, V_2O_3	3580
Vanadium tetroxide, V_2O_4	3580
Vanadium pentoxide, V_2O_5	1275
Sodium metavanadate, $Na_2O.V_2O_5(NaVO_3)$	1165
Sodium pyrovanadate, $2Na_2O.V_2O_5$	1185
Sodium orthovanadate, $3Na_2O.V_2O_5$	1560
Sodium vanadylvanadates, $Na_2O.V_2O_4.V_2O_5$	1160
$5Na_2O.V_2O_4.11V_2O_5$	995

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*Decomposes at a temperature around the melting point.

Ash From Coal-Fired Plants

Coal Ash Formation

More than 90 percent of the coal currently used by electric utilities is burned in pulverized coal boilers. In such boilers, 65 to 80 percent of the ash is produced in the form of fly ash, which is carried out of the combustor in the flue gases and is separated from these gases by electrostatic precipitators and/or mechanical collectors. The remainder of the ash drops to the bottom of the furnace as bottom ash or slag. The amounts of each type of ash produced in the United States during several recent years are listed in table V-24. The percentage of ash collected as fly ash has risen from 65 percent in 1971 to 71 percent in 1975.

The ash residue resulting from the combustion of coal is primarily derived from the inorganic matter in the coal. Table V-25 provides a breakdown of several of the major ash constituents for different ranks of coal. The overall percent ash in the coal varies from 3 to approximately 30 percent. These major ash components can vary widely in concentrations within a particular rank as well as between ranks. Relatively significant concentrations of trace elements are also found in the coal ash. Many of these elements are listed in table V-26 for various ranks of coal. These elements can range from a barely detectable limit to almost 14,000 ppm as the maximum measured for barium in some lignites and subbituminous coals.

During the combustion of coal, the products formed are partitioned into four categories: bottom ash, economizer ash, fly ash, and vapors. The bottom ash is that part of the residue which is fused into particles heavy enough to drop out of the furnace gas stream (air and combustion gases). These particles are collected in the bottom of the furnace. The economizer ash particles are sized approximately between those of bottom and fly ash. This ash is collected in economizer hoppers just beyond the boiler flue gas pass. The fly ash is that part of the ash which is entrained in the combustion gas leaving the boiler. While most of the fly ash is collected in mechanical collectors, baghouses, or electrostatic precipitators, a small quantity of this material may pass through the collectors and be discharged into the atmosphere. The vapor is that part of the coal material which is volatilized during combustion. Some of these vapors are discharged into the atmosphere; others are condensed onto the surface of fly ash particles and may be collected in one of the fly ash collectors. Certain of the trace elements are more volatile than others. The more volatile elements, e.g., mercury, fluorine, thallium, and antimony, will have a strong tendency to vaporize and perhaps condense on the fly ash particles. Some of the vapors may also be trapped inside larger sized bottom ash particles resulting in condensation there as well.

The distribution of the ash between the bottom ash and fly ash fractions is a function of the boiler type (firing method), the type of coal (ash fusion temperature), and the type of boiler bottom (wet

Table V-24

MEGATONS OF COAL ASH COLLECTED IN THE UNITED STATES (19)

Type	1971	1973	1974	1975	1980*	1985**
Fly ash	27.7	34.6	40.4	42.3	-	-
Bottom ash	10.1	10.7	14.3	13.1	-	-
Boiler slag	5.0	4.0	4.8	4.6	-	-
Total	42.8	49.3	59.5	60.0	75.0	120.0
Coal consumed	-	-	390	403	-	-
Calculated average ash content	-	-	15.3%	14.9%	-	-

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*Projection by R. E. Morrison, American Electric Services Co.

**Projection based on expected doubling in coal-fired power generation, 1975 to 1985.

Table V-25

VARIATIONS IN COAL ASH COMPOSITION WITH RANK (19)

Component	Rank			
	Anthracite	Bituminous	Subbituminous	Lignite
SiO_2	48-68	7-68	17-58	6-40
Al_2O_3	25-44	4-39	4-35	4-26
Fe_2O_3	2-10	2-44	3-19	1-34
TiO_2	1-2	0.5-4	0.6-2	0-0.8
CaO	0.2-4	0.7-36	2.2-52	12.4-52
MgO	0.2-1	0.1-4	0.5-8	2.8-14
Na_2O	-	0.2-3	-	0.2-28
K_2O	-	0.2-4	-	0.1-1.3
SO_3	0.1-1	0.1-35	3-16	8.3-32

Table V-26

RANGE IN AMOUNT OF TRACE ELEMENTS PRESENT IN COAL ASHES (19)

(ppm)

	Anthracites			High volatile bituminous		
Element	Max.	Min.	Average	Max.	Min.	Average
Ag	1	1	*	3	1	*
B	130	63	90	2800	90	770
Ba	1340	540	866	4660	210	1253
Be	11	6	9	60	4	1253
Co	165	10	81	305	12	64
Cr	395	210	304	315	74	193
Cu	540	96	405	770	30	293
Ga	71	30	42	98	17	40
Ge	20	20	*	285	20	*
La	220	115	142	270	29	111
Mn	365	58	270	700	31	170
Ni	320	125	220	610	45	154
Pb	120	41	81	1500	32	183
Sc	82	50	61	78	7	32
Sn	4250	19	962	825	10	171
Sr	340	80	177	9600	170	1987
V	310	210	248	840	60	249
Y	120	70	106	285	29	102
Yb	12	5	8	15	3	10
Zn	350	155	*	1200	50	310
Zr	1200	370	688	1450	115	411

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* = Insufficient data to compute an average value.

= Figures encircled indicate the number of samples used to compute average values.

Table V-26 (Continued)

RANGE IN AMOUNT OF TRACE ELEMENTS PRESENT IN COAL ASHES (19)

(ppm)

Element	Low volatile bituminous Max.	Low volatile bituminous Min.	Low volatile bituminous Average	Medium volatile bituminous Max.	Medium volatile bituminous Min.	Medium volatile bituminous Average
Ag	1.4	1	*	1	1	*
B	180	76	123	780	74	218
Ba	2700	96	740	1800	230	396
Be	40	6	16	31	4	13
Co	440	26	172	290	10	105
Cr	490	120	221	230	36	169
Cu	850	76	379	560	130	313
Ga	135	10	41	52	10	*
Ge	20	20	*	20	20	*
La	180	56	110	140	19	83
Mn	780	40	280	4400	125	1432
Ni	350	56		440	20	263
Pb	170	23	89	210	52	96
Sc	155	15	50	110	7	56
Sn	230	10	92	160	29	75
Sr	2500	66	818	1600	40	668
V	480	115	278	870	170	390
Y	460	37	152	340	37	151
Yb	23	4	10	13	4	9
Zn	550	62	231	460	50	195
Zr	620	220	458	540	180	326

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* = Insufficient data to compute an average value.

= Figures encircled indicate the number of samples used to compute average values.

Table V-26 (Continued)

RANGE IN AMOUNT OF TRACE ELEMENTS PRESENT IN COAL ASHES (19)

(ppm)

Element	Lignites and Subbituminous		
	Max.	Min.	Average
Ag	50	1	*
B	1900	320	1020
Ba	13900	550	5027
Be	28	1	6
Co	310	11	45
Cr	140	11	54
Cu	3020	58	655
Ga	30	10	23
Ge	100	20	*
La	90	34	62
Mn	1030	310	688
Ni	420	20	129
Pb	165	20	60
Sc	58	2	18
Sn	660	10	156
Sr	8000	230	4660
V	250	20	125
Y	120	21	51
Yb	10	2	4
Zn	320	50	*
Zr	490	100	245

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* = Insufficient data to compute an average value.

= Figures encircled indicate the number of samples used to compute average values.

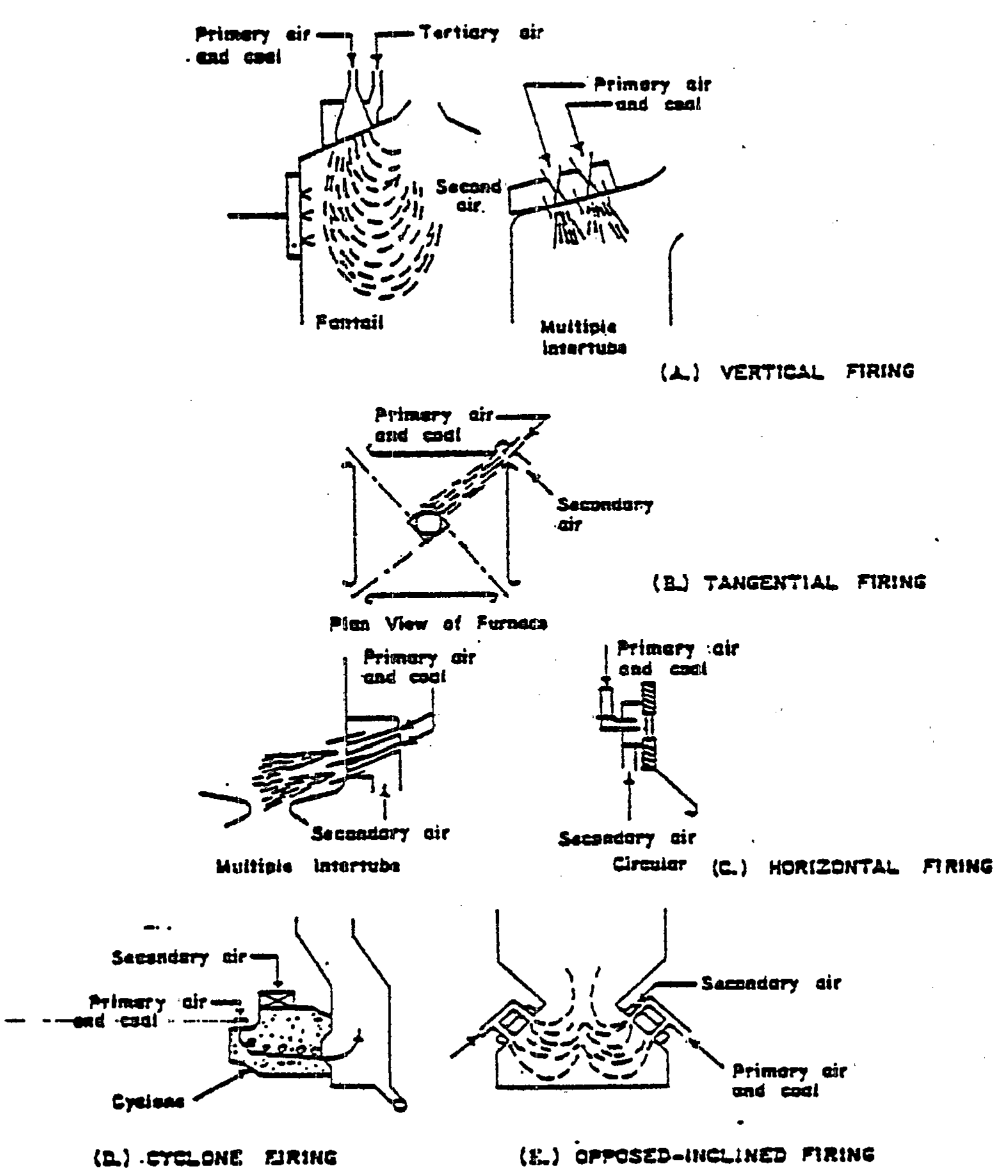
or dry). The first factor, boiler type, is *significant in determining* ash distribution. The boiler types which are currently in use are pulverized coal, cyclone, and spreader stoker. Most modern boilers are the pulverized coal type. The different methods of firing pulverized-coal boilers are shown in figure V-11. Table V-27 shows the relative distributions of bottom ash and fly ash by boiler firing method. The smallest amount of fly ash, approximately 10 percent, is emitted by the cyclone furnace because the ash fusion temperature is exceeded and 80-85 percent of the ash is collected as slag in the bottom ash hopper.

A wet or dry bottom boiler influences the distribution of ash in pulverized coal-fired boilers. Most of the modern pulverized units utilize a dry bottom design. This type of furnace allows the ash to remain in a dry, or non-molten, state and drop through a grate into water-filled hoppers used to collect the ash. Ash in a dry state may reflect either a relatively low boiler design combustion temperature or the ash may contain constituents which are characterized by relatively high melting points. Since the dry ash does not fuse, it can be fairly easily entrained in the combustion gas stream resulting in higher fly ash/bottom ash ratios than in wet bottom boilers. The wet-bottom boiler collects bottom ash in a fused or molten state. This furnace is referred to as a slagging furnace. The relative distributions of bottom ash and fly ash by type of boiler bottom are also shown in table V-27.

Chemical Characteristics of Coal Ash

The chemical compositions of both types of bottom ash, dry or slag, are quite similar. The major species present in bottom ash are silica (20-60 weight percent as SiO_2), alumina (10-35 weight percent as Al_2O_3), ferric oxide (5-35 weight percent as Fe_2O_3), calcium oxide (1-20 weight percent as CaO), magnesium oxide (0.3-0.4 weight percent as MgO), and minor amounts of sodium and potassium oxides (1-4 weight percent). In most instances, the combustion of coal produces more fly ash than bottom ash. Fly ash generally consists of very fine spherical particles, ranging in diameter from 0.5 to 500 microns. The major species present in fly ash are silica (30-50 weight percent as SiO_2), alumina (20-30 weight percent as Al_2O), and titanium dioxide (0.4-1.3 weight percent as TiO_2). Other species which may be present include sulfur trioxide, carbon, boron, phosphorous, uranium, and thorium. Tables V-28 and V-29 provide some ranges for these major species. Species concentration differences between fly ash and bottom ash can vary considerably from one site to another.

In addition to these major components, a number of trace elements are also found in bottom ash and fly ash. Tables V-29 and V-30 present data concerning concentrations of these trace elements for both bottom and fly ash for various utility plants. The trace elemental concentrations can vary considerably within a particular ash or between ashes. Generally, higher trace element concentrations are found in the fly ash than bottom ash; however, there are several cases where bottom ash exceeds fly ash concentrations.


Primary air and coal
Tertiary air
Primary air and coal
Second air.
Fantail
Multiple intertube
Primary air and coal
Secondary air
Plan View of Furnace
Primary air and coal
Primary air and coal
Secondary air
Multiple intertube
Secondary air
Circular
Secondary air
Primary air and coal
Cyclone
Secondary air
Primary air and coal

(A.) VERTICAL FIRING

(B.) TANGENTIAL FIRING

(C.) HORIZONTAL FIRING

(D.) CYCLONE FIRING

(E.) OPPOSED-INCLINED FIRING

Figure V-11
PULVERIZED-COAL FIRING METHODS (19)

Table V-27

COMPARISON OF DISTRIBUTION BETWEEN BOTTOM ASH AND FLY ASH BY TYPE OF BOILERS AND METHOD OF FIRING (19)

Type of Firing*	Type of Boiler Bottom**	% Bottom Ash (typical%)	% Fly Ash (typical%)
PCFR	W	35	65
PCOP	W	35	65
PCTA	W	35	65
PCFR	D	15	85
PCOP	D	15	85
PCTA	D	15	85
CYCL	-	90	10
SPRE	-	35	65

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*PCFR - Pulverized coal front firing
PCOP - Pulverized coal opposed firing
PCTA - Pulverized coal tagential firing
CYCL - Cyclone
SPRE - Spreader stoker

**W - wet bottom
D - dry bottom

Table V-28

MAJOR CHEMICAL CONSTITUENTS OF FLY ASH AND BOTTOM ASH FROM THE SOUTHWESTERN PENNSYLVANIA REGIONS (19)

Constituent	Fly Ash (% by weight)	Bottom ash (% by weight)
Sulfur trioxide	0.01-4.50	0.01-1.0
Phosphorus pentoxide	0.01-0.50	0.01-0.4
Silica	20.1-46.0	19.4-48.9
Iron oxide	7.6-32.9	11.7-40.0
Aluminum oxide	17.4-40.7	18.9-36.2
Calcium oxide	0.1-6.1	0.01-4.2
Magnesium oxide	0.4-1.2	0.5-0.9
Sodium oxide	0.3-0.8	0.2-0.8
Potassium oxide	1.2-2.4	1.7-2.8
Titanium oxide	1.3-2.0	1.3-1.8

Table V-29

COMPARISON OF FLY ASH AND BOTTOM ASH FROM VARIOUS UTILITY PLANTS (19)

Compound or Element	Plant 1		Plant 2		Plant 3		Plant 4		Plant 5		Plant 6	
	FA	BA	FA	BA	FA	BA	FA	BA	BA	BA	BA	BA
SiO_2, %	59	58	57	59	43	50	54	59	NR	NR	42	49
Al_2O_3, %	27	25	20	18.5	21	17	28	24	NR	NR	17	19
Fe_2O_3, %	3.8	4.0	5.8	9.0	5.6	5.5	3.4	3.3	20.4	30.4	17.3	16.0
CaO, %	3.8	4.3	5.7	4.8	17.0	13.0	3.7	3.5	3.2	4.9	3.5	6.4
SO_3, %	0.4	0.3	0.8	0.3	1.7	0.5	0.4	0.1	NR	0.4	NR	NR
MgO, %	0.96	0.88	1.15	0.92	2.23	1.61	1.29	1.17	NR	NR	1.76	2.06
Na_2O, %	1.88	1.77	1.61	1.01	0.4	0.5	1.5	1.5	NR	NR	1.36	0.67
K_2O, %	0.9	0.8	1.1	1.0	1.44	0.64	0.38	0.43	NR	NR	2.4	1.9
P_2O_5, %	0.13	0.06	0.04	0.05	0.70	0.30	1.00	0.75	NR	NR	NR	NR
TiO_2, %	0.43	0.62	1.17	0.67	1.17	0.50	0.83	0.50	NR	NR	1.00	0.68
As, ppm	12	1	8	1	15	3	6	2	8.4	5.8	110	18
Be, ppm	4.3	3	7	7	3	2	7	5	8.0	7.3	NR	NR
Cd, ppm	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0	6.44	1.08	8.0	1.1
Cr, ppm	20	15	50	30	150	70	30	30	206	124	300	152
Cu, ppm	54	37	128	48	69	33	75	40	68	48	140	20
Mg, ppm	0.07	0.01	0.01	0.01	0.03	0.01	0.08	0.01	20.0	0.51	0.05	0.028

Table V-29 (Continued)

COMPARISON OF FLY ASH AND BOTTOM ASH FROM VARIOUS UTILITY PLANTS (19)

Compound or Element	Plant 1		Plant 2		Plant 3		Plant 4		Plant 5		Plant 6	
	FA	BA	FA	BA	FA	BA	FA	BA	BA	BA	BA	BA
Mn, ppm	267	366	150	700	150	150	100	100	249	229	298	295
Ni, ppm	10	10	50	22	70	15	20	10	134	62	207	85
Pb, ppm	70	27	30	30	30	20	70	30	32	8.1	8.0	6.2
Se, ppm	6.9	0.2	7.9	0.7	18.0	1.0	12.0	1.0	26.5	5.6	25	0.08
V, ppm	90	70	150	85	150	70	100	70	341	353	440	260
Zn, ppm	63	24	50	30	71	27	103	45	352	150	740	100
B, ppm	266	143	200	125	300	70	700	300	NR	NR	NR	NR
Co, ppm	7	7	20	12	15	7	15	7	6.0	3.6	39	20.8
F, ppm	140	50	100	50	610	100	250	85	624	10.6	NR	NR

KEY: FA = Fly Ash
BA = Bottom Ash

Table V-30

CONCENTRATIONS OF SELECTED TRACE ELEMENTS IN COAL AND ASH AT PLANT 4710 (19)

	Element Concentration			
Element	Coal[a]	Bottom ash	Inlet fly ash[b]	Outlet fly ash[c]
As	4.45	18	110	440
Ba	65	500	465	750
Br	3.7	2	4	
Cd	0.47	1.1	8.0	51
Ce	8.2	84	84	120
Cl	914	<100	<200	
Co	2.9	20.8	39	65
Cr	18	152	300	900
Cs	1.1	7.7	13	27
Cu	8.3	20	140	
Eu	0.1	1.1	1.3	1.3
Ga	4.5	5	81	
Hf	0.4	4.6	4.1	5.0
Hg	0.122	0.028	0.050	
La	3.8	42	40	42
Mn	33.8	295	298	430
Ni	16	85	207	
Pb	4.9	6.2	80	650
Rb	15.5	102	155	55
Sb	0.5	0.64	12	36
Sc	2.2	20.8	26	88
Se	2.2	0.08	25	36
Sm	1.0	8.2	10.5	9
Sr	23	170	250	
Ta	0.11	0.95	1.4	1.8
Tn	2.1	15	20	26
U	2.18	14.9	30.1	
V	28.5	260	440	1180
Zn	46	100	740	5900

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[a] Mixture of coals from southern Illinois and western Kentucky. Ash content 12%.

[b] Collected upstream from electrostatic precipitator.

[c] Collected downstream from electrostatic precipitator.

Figure V-12 presents the size distribution curves for fly ash and bottom ash. The difference between the 50 percent grain sizes of bottom ash and fly ash is approximately two orders of magnitude with bottom ash being the larger. Fly ash demonstrates various concentrations of trace elements in various size ranges of particles. More specifically, there exists an increased concentration trend with decreasing particle sizes as shown in table V-31.

Those data on the composition of ash particles demonstrate that priority pollutants are present in the dry ashes and therefore can dissolve into water when ash sluicing methods are used. The next section addresses observed concentrations of these materials in ash handling waters. The purpose is to assess the extent to which these materials enter the ash sluicing waters and therefore are discharged from the plants.

Characterization of Ash Pond Overflows

Data From EPA Regional Offices

Table V-32 is a compilation of data obtained for ash pond overflows from various EPA regional offices. These data summarize ash pond effluents where the total suspended solids values are less than 30 ppm. This data was studied to determine whether a correlation existed between TSS values and the corresponding heavy metal concentrations (20). The results from this study of five different metals, i.e., arsenic, nickel, zinc, copper, and selenium, indicated that no correlation existed between these concentrations and TSS values. Additional data on ash pond overflow are available in the 1974 Development Document (1).

Discharge monitoring report data for 17 plants from various EPA regional offices have been summarized. Table V-33 lists metals concentrations for fly ash ponds, bottom ash ponds, and combined pond systems. These metal concentrations are discharge values only; they do not reflect a net discharge based on intake water metals concentrations.

Tennessee Valley Authority Data

Combined Ash Ponds. In 1973, the Tennessee Valley Authority (TVA) began collecting ash pond effluents and water intake samples quarterly for trace metals; calcium, chloride, and silica analyses. A summary of these data for 1973 through 1975 for plants with combined fly ash and bottom ash ponds appears in table V-34. The complete data from which the summary tables where prepared is presented in Appendix A. The summary consists of the average, maximum, and minimum concentrations for each element. The average was calculated by substituting a value equal to the minimum quantifiable concentration (MQC) when the reported value was less than the MQC. Thus, the average may be biased upward if there is a significant number of values less than the MQC. Those elements most likely affected are As, Ba, Be, Cd, Cr, Pb, Hg, Ni, and Se.

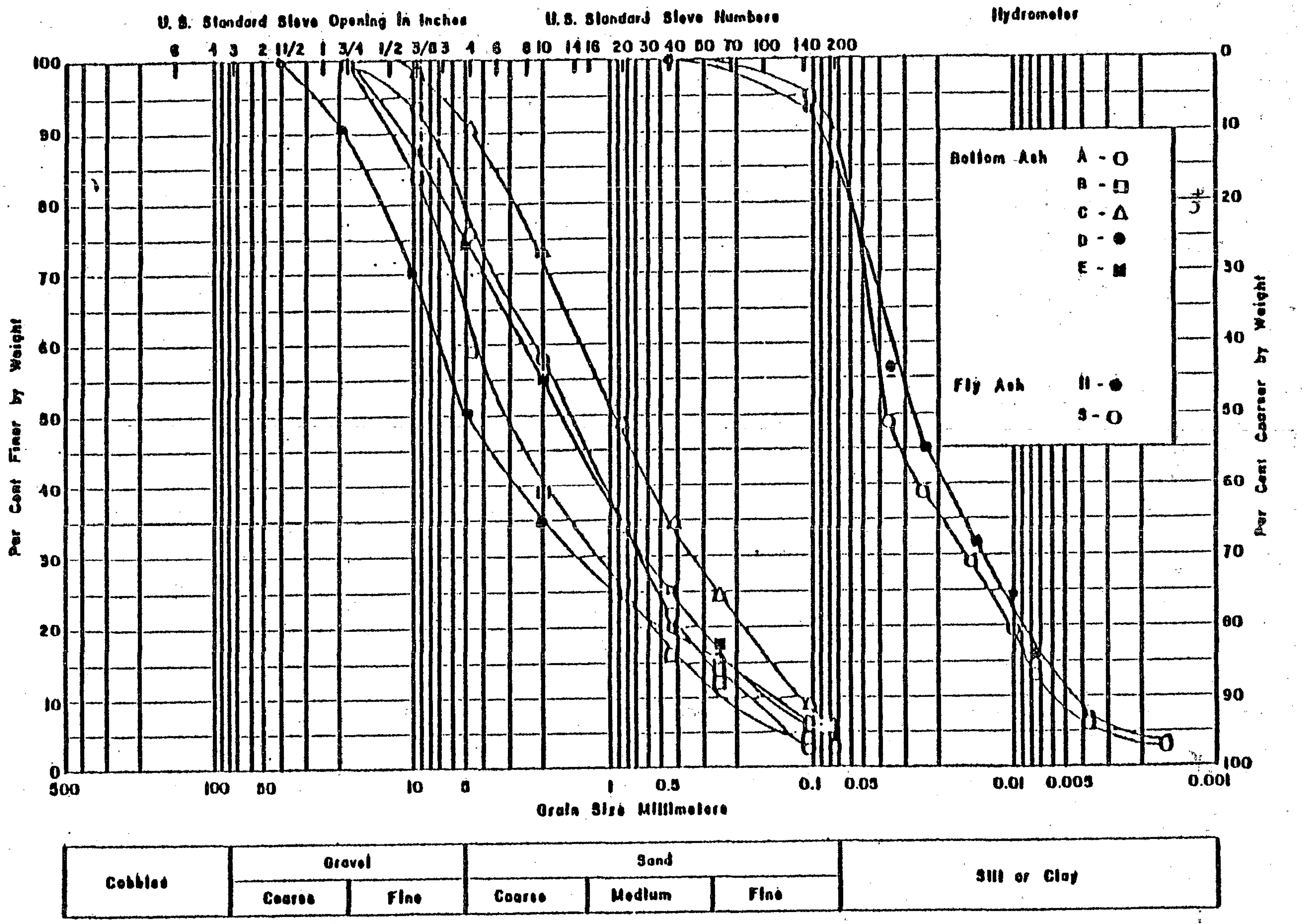

Figure V-12

GRAIN SIZE DISTRIBUTION CURVES FOR BOTTOM ASH AND FLY ASH (19)

Table V-31

ELEMENTS SHOWING PRONOUNCED CONCENTRATION TRENDS WITH DECREASING PARTICLE SIZE (19)

(ppm unless otherwise noted)

Particle Diameter (mm)	Pb	Tl	Sb	Cd	Se	As	Ni	Cr	Zn
A. Fly Ash Retained in Plant									
1. Sieved fractions									
74	140	7	1.5	10	12	180	100	100	500
44-74	160	9	7	10	20	500	140	90	411
2. Aerodynamically sized fractions									
40	90	5	8	10	15	120	300	70	730
30-40	300	5	9	10	15	160	130	140	570
20-30	430	9	8	10	15	200	160	150	480
15-20	520	12	19	10	30	300	200	170	720
10-15	430	15	12	10	30	400	210	170	770
5-10	820	20	25	10	50	800	230	160	1100
5	980	45	31	10	50	370	260	130	1400
3. Analytical method*	a	a	a	a	a	a	a	b	a
B. Airborne Fly Ash									
1. Data									
11.3	1100	29	17	13	13	680	460	740	8100
7.3-11.3	1200	40	27	15	11	800	400	290	9000
4.7-7.3	1500	62	34	18	16	1000	440	460	6600
3.3-4.7	1550	67	34	22	16	900	540	470	3800
2.1-3.3	1500	65	37	26	19	1200	900	1500	15000
1.1-2.1	1600	76	53	35	59	1700	1600	3300	13000
0.65-1.1	...	..	..	..	..	..	..	..	..
2. Analytical method*	d	a	a	d	d	d	d	d	a

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* - (a) DC arc emission spectrometry.
(b) Atomic absorption spectrometry.
(c) X-ray fluorescence spectrometry.
(d) Spark source mass spectromety.

Table V-32

CHARACTERISTICS OF ASH POND OVERFLOWS WITH TOTAL SUSPENDED SOLIDS CONCENTRATIONS LESS THAN 30 mg/l (19)

(mg/l)

Plant Code	Capacity (MW)	Fuel*	No. of Samples	TSS	Fe	Cu	Cd	Ni	As	Pb	Hg	Zn	Se	P	Cr	Oil & Grease
3711	781	c/o	18	24.5	0.36	0.1	0.02	0.1	0.06	0.1	0.002	0.14	0.007	-	0.05	0.23
3708	466	c/o	6	14.7	0.12	0.1	0.02	0.1	0.14	0.1	0.003	0.01	0.005	-	0.05	0.16
4234	598	c/o	1	6.0	0.38	0.01	-	0.0	0.011	0.05		0.03	-	-	-	1.71
0512	1,341	c	7	16.5	0.63	0.01	-	0.01	0.19	0.14	0.001	0.04	0.011	-	0.01	4.0
1226	1,229	c/g	22	9.4	0.92	0.03	-	-	0.02	0.01	0.0006	0.05	-	0.10	0.01	1.2
3713	2,000	c/o	9	5.2	0.20	0.1	.02	0.1	0.03	0.1	0.002	0.08	0.03	-	0.05	0.17
3701	421	c/o	3	18.0	0.47	0.05	0.01	0.05	0.01	0.05	0.001	0.05	0.10	-	0.05	1.0
2105	511	c	5	4.4	0.11	0.006	0	0.0004	0.02	0.004	0	0.005	0.004	-	0.004	1.3
2102	132	c/o	2	10.9	0.2	0.009	-	0.0045	0.03	0.04	0.0004	0.06	0.018	-	0.003	0.26
3805	660	c	1	15	-	0.11	0.002	-	0.06	0.01	0.0001	0.04	-	-	0.02	-
2103	694	c	3	20	0.52	0.15	-	0.005	0.21	0.007	0.0001	0.02	0.01	-	0.005	0.79

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* c - coal
o - oil
g - gas

Table V-33

SUMMARY OF ASH POND OVERFLOW DATA FROM DISCHARGE MONITORING REPORTS (21)

(ppb)

Trace Metal	Fly Ash Ponds[1]			Bottom Ash Ponds[2]			Combined Ponds[3]		
	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
As	10	66	29.2	7	70	21.1	3.5	416	67
Cd	3.5	26.9	11.8	2	16.3	9.7	0	82	18.7
Cr	5	15.2	10.2	4	41.7	15.6	2.5	84.2	30.4
Cu	20	209	84.8	5	70	36.9	0	130	59
Fe	1055	8138	4011	657	10950	3410	80	2600	664.6
Pb	10	200	59.4	10	60	25.5	0	100	40.1
Hg	0.1	1.8	0.6	0.4	1.7	0.8	0	65	3.9
Ni	33	100	61.1	13.3	1345	191.4	0	100	49
Se	2	7.8	4.4	2	10	6.7	1.7	68.3	23.6
Zn	50	1139	358.4	10	302	131.9	10	293	94.9

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[1] Data for 4 facilities

[2] Data for 9 facilities

[3] Data for 20 facilities

Table V-34

SUMMARY OF QUARTERLY TVA TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

			Plant C			Plant C			Plant D			Plant E	
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Aluminum	EFF	0.3	1.5	3.8	0.5	3.4	8	<0.2	1.4	3.8	1.1	2.5	3.4
	RW	0.6	4.7	15	1.3	5.2	15	0.2	0.5	0.9	1.7	2.9	4.3
Ammonia as N	EFF	0.02	0.11	0.34	<0.02	0.09	0.22	<0.01	0.06	0.15	0.03	0.06	0.09
	RW	0.03	0.14	0.33	0.03	0.16	0.29	<0.01	0.04	0.13	0.04	0.07	0.10
Arsenic	EFF	<0.005	0.013	0.05	<0.005	0.022	0.035	<0.005	0.034	0.100	<0.005	0.028	0.13
	RW	<0.005	0.008	0.026	<0.005	0.009	0.026	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Barium	EFF	<0.1	0.2	0.4	<0.1	0.14	0.3	<0.1	0.2	0.3	<0.1	0.2	0.4
	RW	<0.1	0.1	0.2	<0.1	0.14	0.2	<0.1	0.1	0.2	<0.1	0.2	0.4
Beryllium	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	EFF	0.002	0.006	0.013	<0.001	0.002	0.010	<0.001	0.001	0.002	<0.001	0.001	0.002
	RW	<0.001	0.001	0.002	<0.001	0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.002
Calcium	EFF	45	78	100	19	37	89	26	31	37	68	126	170
	RW	15	29	45	15	33	43	23	28	31	14	17	20
Chloride	EFF	7	11	16	7	11	16	2	3	5	5	6	2
	RW	7	11	16	7	11	16	2	3	4	4	5	6
Chromium	EFF	<0.005	0.006	0.008	<0.005	0.009	0.024	<0.005	<0.005	0.008	<0.005	0.017	0.025
	RW	<0.005	0.012	0.041	<0.005	0.013	0.041	<0.005	0.005	<0.005	<0.005	<0.005	<0.005
Copper	EFF	<0.01	0.05	0.10	<0.01	0.06	0.18	<0.01	0.03	0.14	0.02	0.08	0.19
	RW	0.03	0.11	0.22	0.03	0.12	0.22	0.02	0.07	0.22	0.02	0.05	0.08
Cyanide	EFF	<0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	-	-	-	-	-	-	-	-	-	-	-	-
Iron	EFF	0.33	1.7	4.1	0.72	6.0	27	<0.05	0.32	0.67	0.05	0.16	0.39
	RW	1.0	6.5	14	1.4	7.2	14	0.25	0.51	1.00	0.45	1.0	1.6
Lead	EFF	<0.010	0.021	0.069	<0.010	0.017	0.033	<0.010	0.016	0.046	<0.01	0.017	0.036
	RW	<0.010	0.022	0.047	<0.010	0.024	0.047	<0.010	0.012	0.018	<0.01	0.015	0.028
Magnesium	EFF	1.4	10	16	6.3	10	16	7.5	8.3	9.8	0.1	0.3	0.3
	RW	6.5	9.5	14	6.5	6.6	14	7.1	8.0	9.1	3.0	3.4	4.1
Manganese	EFF	0.13	0.20	0.34	0.05	0.18	0.16	<0.01	0.02	0.05	<0.01	0.01	0.02
	RW	0.12	0.31	0.53	0.12	0.31	0.53	0.03	0.07	0.13	0.04	0.05	0.07
Mercury	EFF	<0.0002	0.0034	0.0074	<0.0002	0.0070	0.050	<0.0002	0.0002	0.0003	<0.0002	0.0002	0.0001
	RW	<0.0002	0.0004	0.0016	<0.0002	0.0003	0.0016	<0.0002	0.0002	0.0005	<0.0002	<0.0002	<0.0001
Nickel	EFF	<0.05	0.05	0.07	<0.05	0.06	0.17	<0.05	0.06	0.19	<0.05	<0.05	<0.05
	RW	<0.05	<0.05	<0.05	<0.05	0.05	0.05	<0.05	0.08	0.27	<0.05	<0.05	<0.05

Table V-34 (Continued)

SUMMARY OF QUARTERLY TVA TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

		Plant C			Plant C			Plant D			Plant E		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Selenium	EFF	<0.001	0.010	0.080	<0.001	0.003	0.004	<0.002	0.070	0.170	<0.002	0.007	0.014
	RW	<0.001	0.002	0.004	<0.002	0.002	0.004	<0.002	0.002	0.004	<0.002	<0.002	<0.002
Silica	EFF	4.7	7.4	11	1.5	6.7	14	3.2	4.0	6.2	5.9	7.0	8.4
	RW	5.5	6.1	7.9	5.4	6.2	7.9	3.8	5.2	9.5	4.5	4.7	5.0
Silver	EFF	<0.01	0.01	0.03	<0.01	0.01	0.02	<0.01	0.01	0.01	<0.01	0.01	0.02
	RW	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dissolved Solids	EFF	260	345	460	170	239	420	100	156	200	240	368	420
	RW	160	205	240	160	197	220	110	126	140	80	93	100
Suspended Solids	EFF	3	18	37	4	31	98	3	15	45	2	4	6
	RW	11	46	150	17	51	150	1	14	55	8	18	38
Sulfate	EFF	110	158	200	35	99	280	16	57	84	100	147	210
	RW	0.07	23	52	34	49	68	13	16	20	15	20	25
Zinc	EFF	0.02	0.13	0.27	0.03	0.14	0.16	<0.01	0.03	0.07	<0.03	0.05	0.07
	RW	0.03	0.08	0.13	0.03	0.08	0.13	0.03	0.04	0.07	0.04	0.08	0.18

		Plant F			Plant G			Plant H			Plant I South		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Aluminum	EFF	0.8	1.7	3.1	0.4	1.7	2.9	0.8	1.6	2.9	0.6	1.5	2.6
	RW	<0.1	1.4	3.6	0.1	1.2	4.1	<0.2	1.0	1.6	0.8	1.6	3.0
Ammonia as N	EFF	0.03	0.17	.42	<0.01	0.12	0.62	0.03	0.34	2.60	0.01	0.07	0.31
	RW	0.02	0.08	0.26	0.01	0.04	0.08	0.06	0.23	0.49	0.08	0.05	0.10
Arsenic	EFF	<0.005	0.008	0.040	<0.005	0.030	0.070	<0.005	0.123	0.360	<0.005	0.036	0.163
	RW	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.010	<0.005	<0.005	<0.005
Barium	EFF	<0.1	0.2	0.3	<0.1	0.2	0.4	<0.1	0.2	0.3	<0.1	0.2	0.5
	RW	<0.1	0.1	0.1	<0.1	0.1	0.1	<0.1	0.1	0.2	0.1	0.2	0.3
Beryllium	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	EFF	<0.001	0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.002	<0.001	<0.001	<0.001
	RW	<0.001	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	EFF	67	107	160	38	73	110	34	50	67	44	94	130
	RW	19	27	35	13	20	25	22	28	35	17	19	21
Chloride	EFF	4	5	6	2	4	8	8	14	22	4	6	12
	RW	3	4	4	3	4	5	7	14	28	4	6	8

Table V-34 (Continued)

SUMMARY OF QUARTERLY TVA TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

		Plant F			Plant G			Plant H			Plant I South		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Chromium	EFF	<0.005	0.033	0.072	<0.005	0.011	0.023	<0.005	0.006	0.01	<0.005	0.017	0.030
	RW	<0.005	0.006	0.012	<0.005	0.005	0.010	<0.005	0.005	0.007	<0.005	<0.005	<0.005
Copper	EFF	<0.01	0.03	0.08	<0.01	0.05	0.12	<0.01	0.04	0.14	<0.01	0.06	0.15
	RW	<0.01	0.05	0.08	<0.01	0.07	0.16	0.02	0.07	0.15	0.01	0.07	0.12
Cyanide	EFF	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	-	-	-	-	-	-	-	-	-	-	-	-
Iron	EFF	<0.05	0.22	1.1	0.26	0.53	1.4	0.18	0.56	1.4	<0.05	0.26	0.58
	RW	0.10	1.1	2.1	0.33	1.3	4.6	0.45	1.1	1.7	0.61	1.7	3.5
Lead	EFF	<0.010	0.013	0.040	<0.010	0.014	0.036	0.010	0.015	0.036	<0.01	0.012	0.038
	RW	<0.010	0.019	0.052	<0.010	0.019	0.04	0.010	0.019	0.033	0.01	0.15	0.221
Magnesium	EFF	0.3	1.57	7.2	1.1	2.4	3.1	6.2	7.4	9.7	0.2	1.2	3.7
	RW	3.5	4.2	4.9	3.4	4.0	4.6	5.7	7.4	13.0	2.6	3.3	4.3
Manganese	EFF	<0.01	0.01	0.04	<0.01	0.02	0.04	0.02	0.06	0.10	<0.01	0.05	0.3
	RW	0.06	0.07	0.011	0.05	0.10	0.23	0.10	0.14	0.18	0.01	0.01	0.2
Mercury	EFF	<0.0002	0.0003	0.0009	<0.0002	0.0024	0.014	<0.0002	0.0004	0.0016	<0.0002	0.0003	0.0032
	RW	<0.0002	0.0006	0.0033	<0.0002	0.0049	0.0031	<0.0002	0.0003	0.0008	<0.0002	0.0002	0.0003
Nickel	EFF	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.07	<0.05	0.05	0.05
	RW	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	EFF	0.006	0.014	0.028	<0.001	0.010	0.019	<0.002	0.017	0.034	<0.002	0.012	0.08
	RW	<0.002	<0.002	<0.002	<0.001	0.002	0.004	<0.001	0.002	0.006	<0.001	<0.002	<0.002
Silica	EFF	3.9	6.0	7.6	3.4	4.4	7.1	2.7	4.9	5.6	6.0	7.1	9.1
	RW	3.5	4.5	5.4	3.5	4.4	5.4	2.7	4.9	6.6	3.2	5.4	6.4
Silver	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dissolved Solids	EFF	230	366	540	190	266	320	200	256	350	190	248	370
	RW	90	129	170	70	144	480	110	145	180	90	121	310
Suspended Solids	EFF	<1	4	20	8	19	45	4	10	19	<1	5	15
	RW	6	26	42	5	18	67	10	24	29	4	24	57
Sulfate	EFF	14	160	260	88	182	620	45	98	150	50	81	200
	RW	12	19	23	<1	17	23	16	19	22	10	21	80
Zinc	EFF	<0.01	0.05	0.14	<0.01	0.05	0.10	<0.01	0.05	0.15	<0.01	0.08	0.24
	RW	0.03	0.12	0.22	0.03	0.09	0.13	0.04	0.11	0.33	0.03	0.07	0.12

Table V-34 (Continued)

SUMMARY OF QUARTERLY TVA TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

		Plant J			Plant K			Plant L		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Aluminum	EFF	0.4	2.6	7.6	0.5	1.8	3.1	1.3	2.0	2.6
	RW	0.3	0.7	1.4	0.6	2.0	3.4	0.3	1.2	2.8
Ammonia as N	EFF	0.01	0.05	0.08	0.02	0.06	0.16	0.06	0.52	0.40
	RW	0.01	0.04	0.23	0.04	0.09	0.24	0.04	0.06	0.08
Arsenic	EFF	0.005	0.041	0.130	0.005	0.033	0.100	<0.005	0.032	0.070
	RW	0.005	0.018	0.110	0.005	0.009	0.024	<0.005	0.006	0.010
Barium	EFF	<0.1	0.2	0.3	<0.1	0.2	0.3	<0.1	0.1	0.2
	RW	<0.1	0.2	0.4	<0.1	0.1	0.3	<0.1	0.1	0.2
Beryllium	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	EFF	<0.001	0.001	0.002	<0.001	0.001	0.002	<0.001	0.001	0.004
	RW	<0.001	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium	EFF	20	34	57	44	76	130	32	54	91
	RW	4	15	30	12	20	28	13	17	21
Chloride	EFF	2	5	21	6	10	19	4	6	9
	RW	2	2	4	4	7	10	4	6	8
Chromium	EFF	<0.005	0.005	0.007	<0.005	0.019	0.036	<0.005	0.009	0.018
	RW	<0.005	0.005	0.006	<0.005	0.009	0.027	<0.005	0.009	0.021
Copper	EFF	0.02	0.11	0.73	0.01	0.05	0.10	<0.01	0.06	0.14
	RW	<0.01	0.08	0.13	<0.01	0.07	0.12	<0.01	0.07	0.14
Cyanide	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	-	-	-	-	-	-	-	-	-
Iron	EFF	0.1	2.4	9.4	0.11	0.39	1.2	0.05	0.56	1.00
	RW	0.26	0.7	1.2	0.66	1.9	3.3	0.28	1.03	2.40
Lead	EFF	<0.010	0.015	0.038	0.010	0.017	0.048	0.010	0.017	0.043
	RW	<0.010	0.010	0.018	0.01	0.01	0.03	0.010	0.016	0.032
Magnesium	EFF	3.9	6.7	9.3	0.4	1.6	3.6	0.4	2.6	4.2
	RW	1.2	4.5	8.3	2.5	4.3	6.9	3.4	3.9	4.4
Manganese	EFF	0.05	0.38	0.79	0.01	0.02	0.04	0.01	0.03	0.13
	RW	0.03	0.07	0.18	0.07	0.10	0.18	0.03	0.07	0.12
Mercury	EFF	<0.0002	0.0003	0.0008	<0.0002	0.0003	0.0008	0.0002	0.0003	0.0009
	RW	<0.0002	0.0003	0.0009	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel	EFF	<0.05	0.05	0.08	<0.05	0.06	0.22	<0.05	<0.05	<0.05
	RW	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Table V-34 (Continued)

SUMMARY OF QUARTERLY TVA TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

		Plant J			Plant K			Plant L		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Selenium	EFF	<0.001	0.004	0.008	<0.002	0.010	0.016	0.002	0.010	0.020
	RW	<0.001	0.003	0.008	<0.001	0.002	0.002	<0.001	0.002	0.002
Silica	EFF	3.5	6.4	8.7	4.0	6.7	8.8	4.5	5.7	9.1
	RW	1.0	3.9	5.0	2.5	4.6	5.9	3.6	5.1	5.8
Silver	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dissolved Solids	EFF	140	202	250	180	240	310	140	211	260
	RW	30	89	210	80	106	150	70	88	100
Suspended Solids	EFF	1	15	81	3	8	26	3	12	50
	RW	5	13	35	17	29	60	4	14	43
Sulfate	EFF	56	119	180	54	83	110	6	80	110
	RW	9	22	80	12	20	31	9	13	16
Zinc	EFF	0.02	0.07	0.25	0.01	0.05	0.11	0.02	0.04	0.06
	RW	0.03	0.06	0.09	0.04	0.07	0.11	0.03	0.06	0.09

NOTE: Effluent data based on years 1973-1975
Raw water intake data based on years 1974 and 1975

KEY: EFF - effluent
RW - raw water (intakes)

The average concentrations of calcium, chloride, iron, magnesium, and manganese varied considerably from one effluent to another, while the average concentrations of aluminum, arsenic, silica, and sulfate varied only slightly. The average concentrations of barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc were approximately the same in all the ash pond effluents. The combined ash pond effluent at Plant D had a considerably higher concentration of selenium (70 ppb) than the rest of the effluents, while the ash pond effluent from Plant H had a considerably higher concentration of arsenic (123 ppb) than the others. The plants, other than Plant H, had less than 50 ppb arsenic in the effluents.

TVA statistically compared the intake water characteristics to those of the effluents for Plants E, G, H, and J. Of particular importance was the evaluation of a potential relationship between priority pollutants (metals) and suspended solids. Essentially no correlation existed between suspended solids in the ash pond effluent and intake water quality characteristics.

Relationships between the ash pond effluent and the plant operating conditions were also studied by TVA. Table V-35 provides a summary of the TVA plant operating conditions during collection of the ash pond effluent data. No bottom ash characteristic data were available for this study. Statistical correlations of the data show the pH of the ash pond effluent is influenced mainly by the calcium content of the fly ash and by the sulfur content of the coal. As the percent CaO goes up, the alkalinity of the ash pond effluent increases. The number of ash ponds in which the average concentration of each trace element shows a net increase from the ash pond influent to the overflow is presented in table V-36. More than half of the ash ponds increase the concentrations of Al, NH_3, As, Ba, Cd, Ca, Cl, Cr, Pb, Hg, Ni, Se, Si, SO_4 and Zn over that of the intake water. According to studies completed by TVA (22), the range over which the trace metals vary in the ash pond effluent appeared to be as great or greater than that in the intake water.

Separate Bottom Ash and Fly Ash Ponds. Certain utilities utilize separate fly ash and bottom ash ponds for handling the sluice water in their ash pond effluent systems. Table V-37 provides both ash pond effluent and raw water trace element and solids data for the separate fly ash and bottom ash ponds for two TVA plants. The complete data from which the summary table was prepared is presented in Appendix A. Most of the elements appeared in greater concentrations in the fly ash effluent than in the bottom ash effluent for Plant A. On the average, the concentrations observed in Plant A fly ash effluents are at least several times as great as the observed bottom ash concentrations. For Plant B, the fly ash and bottom ash effluent concentrations are approximately equal. Comparison of ash effluent concentrations to the raw water concentrations for Plant A reveals that the bottom ash concentrations are approximately equal to the raw water concentrations. The Plant A fly ash concentrations generally exceed the raw water concentrations. For Plant B, the bottom ash and fly ash effluent concentrations generally exceed the raw water

Table V-35

SUMMARY OF PLANT OPERATION CONDITIONS AND ASH CHARACTERISTICS OF TVA COAL-FIRED POWER PLANTS (22)

Parameters	Plant C	Plant D	Plant E	Plant F	Plant G	Plant H	Plant I	Plant J	Plant K	Plant L
Method of Firing	Cyclone	Tangential	Circular Wall Burner	Opposed	Tangential	Tangential	Circular Wall Burner	Tangential	Circular Wall Burner	Circular Wall Burner
Coal Source	W. Kentucky	E. Kentucky	W. Kentucky	W. Kentucky S. Illinois	W. Kentucky	Virginia E. Kentucky E. Tennessee	W. Kentucky	E. Kentucky E. Tennessee	S. Illinois W. Kentucky	W. Kentucky N. Alabama
Ash Content in Coal, %	11	15.5	15.3	16.3	15.7	15	14	19.1	15.6	16
Fly Ash of Total Ash, %	30	75	67	80	80	67	70	75	75	75
Bottom Ash of Total Ash, %	70	25	33	20	20	33	30	25	25	25
Sulfur Content in Coal, %	3.0	1.2	4.1	3.7	3.5	1.8	3.7	2.1	2.8	2.8
Coal Usage at Full Load (tons/day)	7848	8420	12897	24525	10503	8057	14460	16193	15304	17691
Number of Units	3	1	5	2	4	4	10	9	10	8
ESP Efficiency, %	-	99	74	99	60	-	75	70	60	60
Mechanical Ash Collector Efficiency, %	90-99	-	80	-	-	-	-	95	95	99
Overall Efficiency, %	-	99	95	-	98-99	99	75.5	98	98	70
Sluice Water to Ash Ratio (gal/ton)	23065	10770	9585	19490	12345	11425	42430	9520	17265	15370
pH of Intake Water	7.4	7.5	7.0	7.4	7.3	7.0	7.4	7.6	7.6	7.5
Suspended Solids Concentration of Intake Water (mg/l)	81	15	17	24	12	21	15	15	38	6
Alkalinity of Intake Water (mg/l as $CaCO_3$)	83	95	53	69	63	73	58	55	66	63
% 310_2 in Fly Ash	47.6	NA	46.9	NA	53.7	52.5	58.7	50.4	NA	45.3
% CaO in Fly Ash	1.72	NA	4.66	NA	2.36	2.19	3.17	1.92	NA	4.91
% Fe_2O_3 in Fly Ash	11.3	NA	14.9	NA	9.6	10.2	10.7	11.6	NA	17.0
% Al_2O_3 in Fly Ash	22.7	NA	18.6	NA	26.4	25.5	23.9	25.2	NA	27.0
% H_3O in Fly Ash	0.93	NA	1.33	NA	1.12	1.42	1.24	1.29	NA	1.22
% SO_3 in Fly Ash	2.2	NA	1.5	NA	1.09	1.9	1.2	0.54	NA	1.16
% Moisture in Fly Ash	1.04	NA	0.32	NA	0.37	0.63	0.22	0.21	NA	0.87
pH of Fly Ash	2.9	NA	11.8	NA	4.5	3.6	4.6	4.0	NA	6.5
Ash Pond Effluent	7.1	8.4	11.1	11.1	9.5	8.7	11.0	7.5	10.8	10.1
Ash Pond Effluent Suspended Solids (mg/l)	30	19	<10	10	20	19	19	25	17	15

NOTE: Intake water characteristics based on 1974 and 1975 weekly samples.
Ash pond effluent characteristics based on 1970-1975 weekly samples.
All plants use combined fly ash/bottom ash ponds.

Table V-36

NUMBER OF ASH PONDS IN WHICH AVERAGE EFFLUENT CONCENTRATIONS OF SELECTED TRACE ELEMENTS EXCEED THOSE OF THE INTAKE WATER (22)

Element	No. Exceeding
Aluminum	10
Ammonia	9
Arsenic	15
Barium	7
Beryllium	1
Cadmium	7
Calcium	15
Chloride	8
Chromium	10
Copper	5
Cyanide	3
Iron	4
Lead	8
Magnesium	6
Manganese	5
Mercury	12
Nickel	10
Selenium	14
Silica	12
Silver	2
Sulfate	15
Zinc	7

NOTE: The total number of ash ponds is 15.

Table V-37

SUMMARY OF QUARTERLY TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

		Plant A Bottom Ash			Plant A Fly Ash			Plant B Bottom Ash			Plant B Fly Ash		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Aluminum	EFF	0.5	3.2	8.0	3.6	7.9	13	0.4	2.2	8.6	0.6	1.6	4.8
	RW	0.5	2.6	6.7	0.5	2.6	6.7	0.4	0.8	1.6	0.4	0.8	1.6
Ammonia as N	EFF	0.04	0.11	0.34	0.02	0.75	3.1	<0.01	0.07	0.31	<0.01	0.07	0.20
	RW	0.02	0.07	0.14	0.02	0.07	0.14	0.04	0.08	0.08	0.04	0.08	0.08
Arsenic	EFF	<0.005	0.007	0.015	0.005	0.011	0.035	<0.005	0.014	0.055	<0.005	0.029	0.070
	RW	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Barium	EFF	<0.1	0.1	0.1	<0.1	0.2	0.4	<0.1	0.1	0.3	<0.1	0.1	0.2
	RW	<0.1	0.2	0.4	<0.1	0.2	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium	EFF	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	EFF	<0.001	0.001	0.002	0.023	0.038	0.052	<0.001	0.002	0.01	<0.001	0.001	0.002
	RW	<0.001	0.001	0.004	0.001	0.001	0.004	<0.001	0.004	0.01	<0.001	0.004	0.01
Calcium	EFF	23	38	67	88	126	180	17	50	200	27	152	430
	RW	21	35	48	21	35	48	17	19	20	17	19	20
Chloride	EFF	4	7	15	4	7	14	5	7	11	4	6	8
	RW	4	6	10	4	6	10	4	5	7	4	5	7
Chromium	EFF	<0.005	0.007	0.023	0.012	0.072	0.170	<0.005	0.009	0.026	<0.005	0.013	0.036
	RW	<0.005	0.010	0.024	0.005	0.010	0.024	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	EFF	0.01	0.07	0.14	0.16	0.33	0.45	<0.01	0.06	0.20	<0.01	0.03	0.10
	RW	0.04	0.09	0.19	0.04	0.09	0.19	<0.01	0.02	0.02	<0.01	0.02	0.02
Cyanide	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	-	-	-	-	-	-	-	-	-	-	-	-
Iron	EFF	1.7	5.2	11	0.33	2.3	8.6	0.26	4.7	30	0.14	1.4	7.1
	RW	1.1	2.7	6.7	1.1	2.7	6.7	0.32	0.57	0.90	0.32	0.57	0.90
Lead	EFF	<0.010	0.017	0.031	<0.010	0.066	0.200	<0.010	0.018	0.048	<0.01	0.015	0.030
	RW	<0.010	0.021	0.038	<0.010	0.021	0.038	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Magnesium	EFF	0.3	6.0	9.3	9.4	14	20	4.1	6.2	21	0.2	3.6	6.8
	RW	4.1	6.1	8.0	4.1	6.1	8.0	3.6	4.3	4.7	3.6	4.3	4.7
Manganese	EFF	0.07	0.17	0.26	0.29	0.49	0.63	0.02	0.40	3.6	0.02	0.12	0.63
	RW	0.08	0.13	0.25	0.08	0.13	0.25	0.04	0.06	0.08	0.04	0.06	0.08
Mercury	EFF	<0.0002	0.0005	0.0026	<0.0002	0.0003	0.0006	<0.0002	0.0009	0.0042	<0.0002	0.0008	0.0056
	RW	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel	EFF	<0.05	0.06	0.12	<0.05	0.08	0.13	<0.05	0.06	0.14	<0.05	0.05	0.03
	RW	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	EFF	<0.001	0.002	0.004	<0.001	0.002	0.004	<0.001	0.007	0.056	0.001	0.015	0.064
	RW	<0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	0.002	0.002	<0.002	<0.002	<0.002

Table V-37 (Continued)

SUMMARY OF QUARTERLY TRACE METAL DATA FOR ASH POND INTAKE AND EFFLUENT STREAMS (22)

		Plant A Bottom Ash			Plant A Fly Ash			Plant B Bottom Ash			Plant B Fly Ash		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Silica	EFF	5.6	7.4	9.3	9.3	13	20	3.7	6.4	22	3.1	7.1	22
	RW	1.7	5.6	8.0	1.7	5.6	8.0	3.2	5.4	7.2	3.2	5.4	7.2
Silver	EFF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.05	0.01	0.02	0.05
Dissolved Solids	EFF	140	185	260	470	593	700	110	229	710	40	458	1100
	RW	120	154	200	120	154	200	90	93	100	90	93	100
Suspended Solids	EFF	5	52	200	1	6	17	2	23	78	2	13	39
	RW	14	60	190	14	60	190	8	11	14	8	11	14
Sulfate	EFF	23	45	80	240	346	440	20	102	470	17	214	480
	RW	6	21	30	6	21	30	9	12	18	9	12	18
Zinc	EFF	0.02	0.08	0.16	0.82	1.4	2.7	0.02	0.13	0.55	0.01	0.05	0.13
	RW	0.06	0.09	0.14	0.06	0.09	0.14	0.01	0.02	0.04	0.01	0.02	0.04

NOTE: Effluent data based on years 1973-1975
Raw water intake data based on years 1974 and 1975

KEY: EFF - effluent
RW - raw water (intakes)

concentrations. In both plants, iron was found in higher concentrations in the bottom ash than the fly ash. Selenium, mercury, and cyanide were found in very low concentrations. Arsenic was below 0.05 mg/l in all four ponds. In both plants, the dissolved solids were higher in the fly ash ponds while the suspended solids were higher in the bottom ash ponds.

Table V-38 provides plant operating information for Plants A and B. Plant A has a cyclone furnace that produces approximately 70 percent bottom ash and 30 percent fly ash, while Plant B has pulverized coal-fired boilers which produce 50 percent bottom ash and 50 percent fly ash.

NUS Corporation Data. Table V-39 provides trace element information for separate fly ash and bottom ash ponds. These data were compiled by NUS Corporation (23). Nickel and manganese was evenly distributed between both types of ash ponds; zinc was slightly higher in the fly ash ponds; copper was slightly higher in the bottom ash ponds. The fly ash pond of southeastern Ohio was the only pond that demonstrated arsenic levels which exceeded 50 ppb.

Sampling Program Results

Screening Phase. The purpose of the screening phase of the sampling program was to identify the pollutants in the discharge streams. The screening phase for the ash transport stream included the sampling of five ash pond overflows. Table V-40 presents the analytical results for sampling for the 129 priority pollutants.

Verification Phase. The verification phase involved the sampling of nine facilities for ash pond overflow to further quantify those effluent species identified in the screening program. The data reported as a result of this effort are summarized in table V-41. One of the plants (1226) was sampled by two laboratories and both sets of results are reported.

Arsenic Levels

Table V-42 presents data for plants in which arsenic concentrations in the ash pond discharge streams exceed the Interim Drinking Water Standard of 50 ppb. The maximum arsenic level is 416 ppb. Other data concerning arsenic levels in ash pond effluents are given in table V-43. Two plants exceed the 50 ppb level. Intake water concentrations for arsenic are provided in tables V-40, V-41, and V-43. The increases in arsenic concentrations, from the plant intake water to the ash pond overflow, range from no increase at all for a number of plants to a 300 ppb increase for plant 2603 in Table V-41. The range of arsenic levels in ash pond effluents is from less than 1 ppb to 416 ppb.

Table V-38

SUMMARY OF PLANT OPERATING CONDITIONS AND ASH CHARACTERISTICS OF TVA COAL-FIRED POWER PLANTS

Parameters	Plant A	Plant B
Method of Firing	Cyclone	Circular Wall Burners
Coal Source	W. Kentucky	W. Kentucky
Ash Content in Coal, %	18.8	14.8
Fly Ash of Total Ash, %	30	50
Bottom Ash of Total Ash, %	70	50
Sulfur Content in Coal, %	4.1	-
Coal Usage at Full Load (tons/day)	22901	3314
Number of Units	3	4
ESP Efficiency, %	-	-
Mechanical Ash Collector Efficiency, %	98	-
Overall Efficiency, %	98	-
Sluice Water to Ash Ratio (gal/ton)	12380[f] 9810[b]	- -
pH of Intake Water	7.7	7.5
Suspended Solids Concentration of Intake Water (mg/l)	60	41
Alkalinity of Intake Water (mg/l as $CaCO_3$)	97	56
% SiO_2 in Fly Ash	NA	NA
% CaO in Fly Ash	NA	NA
% Fe_2O_3 in Fly Ash	NA	NA
% Al_2O_3 in Fly Ash	NA	NA
% MgO in Fly Ash	NA	NA

Table V-38 (Continued)

SUMMARY OF PLANT OPERATING CONDITIONS AND ASH CHARACTERISTICS OF TVA COAL-FIRED POWER PLANTS

Parameters	Plant A	Plant B
Ash Pond Effluent pH	4.4[f] 7.2[b]	9.8[f] 8.0[b]
Ash Pond Effluent Suspended Solids (mg/1)	25[f] 55[b]	85[f] 64[b]

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[f] Fly Ash Pond Only

[b] Bottom Ash Pond Only

NOTE: Intake water characteristics based on 1974 and 1975 weekly samples. Ash pond effluent characteristics based on 1970-1075 weekly samples.

Table V-39

ASH POND EFFLUENT TRACE ELEMENT CONCENTRATIONS* (23)

(ppb)

Station Location	Ash Pond Type	Arsenic	Copper	Nickel	Zinc	Manganese
Western W. Virginia	Bottom	<5	<1	11	10	130
Eastern Ohio	Bottom	7	10	30	90	300
Southern Ohio	Bottom	<5	60	30	40	180
Eastern Michigan	Bottom	30	<1	20	270	70
Southeast Michigan	Fly	40	<1	20	240	5
Southeast Ohio	Fly	200	6	30	50	4
Eastern Missouri	Bottom	20	3	20	50	240
Central Utah	Bottom	<5	6	1	5	5
Western W. Virginia	Fly	8	5	30	40	550
Southern Ohio	Fly	10	4	<1	80	10

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*Minimum Quantifiable Concentrations/Arsenic (5 ppb), Copper (1 ppb), Nickel (1 ppb), Zinc (1 ppb), Manganese (1 ppb).

Table V-40

SCREENING DATA FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb) Intake	Concentration (ppb) Discharge
4222 (Combined Fly Ash and Bottom Ash)	Methylene Chloride	12	27
	Trichlorofluoromethane	ND<1/1	6/ND<1
	Phenol	2/<100	1/260
	Bis(2-Ethylhexyl) Phthalate	2	1
	Butyl Benzyl Phthalate	1	1
	Toluene	3/2	3/4
	Methylene Chloride	8	18
	Antimony, Total	<5	29
	Arsenic, Total	<5	160
	Beryllium, Total	<5	20
	Chromium, Total	<5	11
	Copper, Total	16	6
	Mercury, Total	0.26	0.21
	Nickel, Total	6	8
	Selenium, Total	<5	32
	Zinc, Total	14	10
2414 (Combined Fly Ash and Bottom Ash)	Benzene	6/13	3/2
	Chloroform	2	ND < 1
	Methylene Chloride	4/1	ND<1/2
	Phenol	45/<100	ND<1/31
	Bis(2-Ethylhexyl) Phthalate	12	40
	Diethyl Phthalate	3	ND < 1
	Toluene	21/1	11/70
	Cis 1,2-Dichloroethylene	ND<1/15	30/ND<1
	1,1,1-Trichloroethane	ND < 1	1
	1,4-Dichlorobenzene	ND < 1	1
	Ethylbenzene	1	2
	Arsenic, Total	5	50
	Asbestos (fibers/liter)	28,400	0
	Chromium, Total	<5	14
	Copper, Total	21	66
	Cyanide, Total	<20	80
	Lead, Total	7	8
	Mercury, Total	0.88	0.63
	Nickel, Total	8	144
	Selenium, Total	15	22
	Silver, Total	45	52
	Thallium, Total	6	8
	Zinc, Total	<5	41

Table V-40 (Continued)

SCREENING DATA FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
3805 (Combined Fly Ash and Bottom Ash)	Benzene	1/6	ND<1/2
	1,1,1-Trichloroethane	2	ND < 1
	Chloroform	1/3	2/4
	1,1-Dichloroethylene	ND<1/1	1/ND<1
	Ethylbenzene	20	ND < 1
	Methylene Chloride	22/10	8/15
	Trichlorofluoromethane	40	1
	Phenol	2	3
	Bis(2-Ethylhexyl) Phthalate	ND < 1	6
	Tetrachloroethylene	1	ND < 1
	Toluene	42/14	4/6
	Trichloroethylene	2	ND < 1
	Cis 1,2-Dichloroethylene	3	ND < 1
	Chromium, Total	39	<5
	Copper, Total	6	5
	Lead, Total	19	<5
	Mercury, Total	0.23	0.32
	Selenium, Total	11	<5
	Silver, Total	12	<5
	Zinc, Total	5	5
3404 (Bottom Ash)	Benzene	1	1
	Chloroform	3/1	ND<1/1
	1,1-Dichloroethylene	1/1	1/ND<1
	Methylene Chloride	20/1	4/ND<1
	Phenol	ND<1/36	1/20
	Bis(2-Ethylhexyl) Phthalate	11	9
	Di-N-Butyl Phthalate	4	1
	Toluene	3/3	3/2
	Antimony, Total	11	12
	Arsenic, Total	<5	14
	Cadmium, Total	15	13
	Chromium, Total	16	20
	Copper, Total	25	29
	Lead, Total	5	5
	Mercury, Total	0.34	0.32
	Nickel, Total	21	33
	Selenium, Total	55	42
	Silver, Total	40	19
	Zinc, Total	<5	8

Table V-40 (Continued)

SCREENING DATA FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
2512 (Fly Ash)	Benzene	ND<1/1	1/ND<1
	1,1,1-Trichloroethane	ND<1/ND<1	2/3
	Chloroform	2/3	1/ND<1
	1,1-Dichloroethylene	1/2	ND<1/2
	Ethylbenzene	ND<1/1	1/ND<1
	Methylene Chloride	23/12	35/5
	Bis(2-Ethylhexyl) Phthalate	1	27
	Di-N-Butyl Phthalate	ND < 1	1
	Toluene	2/7	4/3
	1,4-Dichlorobenzene	7	ND < 1
	Antimony, Total	<5	5
	Arsenic, Total	6	7
	Copper, Total	22	14
	Lead, Total	<5	12
	Mercury, Total	0.21	0.22
	Nickel, Total	7	1,500
	Selenium, Total	35	32
	Zinc, Total	<5	17

Table V-41

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1742 (Combined Fly Ash and Bottom Ash Pond)	Cadmium, Total (Dissolved)	40(5)	10(9)
	Chromium, Total (Dissolved)	24/20*(ND/30)*	23/2000*(ND/30)*
	Copper, Total (Dissolved)	21/20*(ND/9)*	106/50*(54/7)*
	Lead, Total (Dissolved)	9/ND<20*(ND/90)*	9/ND<20*(3/100)*
	Mercury, Total (Dissolved)	ND < 0.5	1.5(1)
	Nickel, Total (Dissolved)	17/ND<5*(ND/40)*	39/900*(1/40)
	Zinc, Total (Dissolved)	ND/70*(30/ND<60)*	ND/ND<60*(20/ND<60)*
	Total Dissolved Solids	340,000	370,000
	Total Suspended Solids	100,000	15,000
	Total Organic Carbon	10,000	150,000
	Aluminum, Total	2,000	ND < 50
	Barium, Total (Dissolved)	60(30)	50(50)
	Boron, Total (Dissolved)	90(200)	200(400)
	Calcium, Total (Dissolved)	51,000(44,000)	51,000(53,000)
	Cobalt, Total (Dissolved)	10(7)	50(10)
	Manganese, Total (Dissolved)	200(10)	300(ND<5)
	Magnesium, Total (Dissolved)	23,000(22,000)	20,000(22,000)
	Molybdenum, Total (Dissolved)	9(40)	50(50)
	Phenolics, 4AAP	6	12
	Sodium, Total (Dissolved)	21,000(20,000)	26,000(25,000)
	Tin, Total (Dissolved)	30(60)	30(60)
	Titanium, Total	40	ND < 20
	Iron, Total	4,000	8,000
	Vanadium, Total (Dissolved)	ND/ND<10*(ND/20)	ND/20*(ND/30)*
	Silver (Dissolved)	(ND/10)*	(ND/10)*

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1741 (Bottom Ash)	Cadmium, Total (Dissolved)	ND < 2(3)	10(8)
	Chromium, Total (Dissolved)	ND/4,000*(ND/20)*	9/ND<5*(ND/20)*
	Copper, Total (Dissolved)	ND/90*(ND/9)*	35/10*(13/7)*
	Lead, Total (Dissolved)	ND/20*(ND/100)*	14/ND<20*(ND<4/100)*
	Mercury, Total	ND	1
	Nickel, Total (Dissolved)	ND/2000*(ND/20)*	15/ND<5*(ND/50)*
	Zinc, Total (Dissolved)	ND/ND<60*(20/ND<60)*	ND/70*(ND/100)*
	Total Dissolved Solids	130,000	4,000
	Total Suspended Solids	10,000	160,000
	Total Organic Carbon	5,000	17,000
	Aluminum, Total	200	ND < 50
	Barium, Total (Dissolved)	30(30)	60(60)
	Boron, Total (Dissolved)	70(ND<50)	80(100)
	Calcium, Total (Dissolved)	10,000(13,000)	21,000(24,000)
	Cobalt, Total (Dissolved)	40(6)	ND < 5 (8)
	Manganese, Total (Dissolved)	800(ND<5)	100(700)
	Magnesium, Total (Dissolved)	9,800(5,100)	5,600(5,800)
	Molybdenum, Total (Dissolved)	60(30)	8(30)
	Phenolics, 4AAP	ND	11
	Sodium, Total (Dissolved)	D<15,000(D<15,000)	D<15,000(D<15,000)
	Tin, Total (Dissolved)	ND < 5(30)	20(20)
	Titanium, Total	30	ND < 30
	Iron, Total	20,000	200
	Vanadium, Total (Dissolved)	ND/10(ND<10/ND)*	ND/ND<10(ND/10)
	Beryllium, Dissolved)	(3)	(2)
	Silver, (Dissolved)	(ND/6)*	(ND/9)*

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake†	Discharge
1741 (Fly Ash)	Cadmium, Total (Dissolved)		90(70)
	Chromium, Total (Dissolved)		12/6*(ND/20)*
	Copper, Total (Dissolved)		15/9*(4/7)*
	Lead, Total (Dissolved)		120/ND<20*(6/80)*
	Nickel, Total (Dissolved)		100/50*(58/90)*
	Zinc, Total (Disslved)		1400/1000*(ND/1000)*
	Total Dissolved Solids		790,000
	Total Suspended Solids		6,000
	Total Organic Carbon		18,000
	Barium, Total (Dissolved)		100(100)
	Boron, Total (Dissolved)		3,000(5,000)
	Calcium, Total (Dissolved)		140,000(160,000)
	Cobalt, Total (Dissolved)		10(20)
	Manganese, Total (Dissolved)		1,000(1000)
	Magnesium, Total (Dissolved)		9,500(10,000)
	Molybdenum, Total (Dissolved)		200(300)
	Phenolics, 4AAP		9
	Sodium, Total (Dissolved)		D<15,000(D<15,000)
	Tin, Total (Dissolved)		30(20)
	Titanium, Total		20
	Iron, Total		900
	Beryllium, (Dissolved)		2
	Silver (Dissolved)		(ND/10)*
	Vanadium (Dissolved)		(ND/20)*
	Yttrium (Dissolved)		(40)

†Same intake as for Plant 1741, Bottom Ash Pond.

*These multiple results represent analyses by multiple analytical labs.

()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1226 (Combined Fly Ash and Bottom Ash Pond)	Antimony, Total	ND/7*	ND/7*
	Arsenic, Total	ND/3*	ND/9*
	Cadmium, Total	2.1/ND<2*	2/ND<2*
	Chromium, Total	ND/7/7*	ND/6/10*
	Copper, Total (Dissolved)	10/12/10*(10)	18/14/10*(13/9)*
	Lead, Total (Dissolved)	12/10/ND<20*(7/ND<20)*	9/4*(4/ND<20)*
	Mercury, Total	ND<1/0.5*	ND<0.5/ND<0.2*
	Nickel, Total (Dissolved)	27/1.5/ND<5*(29/ND<5)*	ND/5.5/5*(ND/ND<5)*
	Selenium, Total	ND/ND<2*	ND/8*
	Silver, Total	ND/1.5/ND<1*	ND/0.5/ND<1*
	Zinc, Total (Dissolved)	ND/9/70*(50/ND<60)*	ND/7/ND<60*(ND/ND<60)*
	Total Dissolved Solids	190,000	2,350,000
	Total Suspended Solids	14,000	12,000
	Aluminum, Total (Dissolved)	700(100)	300(500)
	Barium, Total (Dissolved)	20(20)	60(60)
	Boron, Total (Dissolved)	ND < 50(70)	400(900)
	Calcium, Total (Dissolved)	6,900(D<5,000)	34,000(32,000)
	Cobalt, Total	7	ND < 5
	Manganese, Total (Dissolved)	200(200)	30(6)
	Magnesium, Total (Dissolved)	4,500(5,000)	7,300(7,500)
	Molybdenum, Total (Dissolved)	ND < 5(ND<5)	100(100)
	Phenolics, 4AAP	12	17
	Sodium, Total (Dissolved)	33,000(36,000)	66,000(72,000)
	Titanium, Total	20	ND < 20
	Iron, Total (Dissolved)	2,000(1,000)	600(ND<200)
	Vanadium, Total (Dissolved)	ND/40/ND<10*(ND/ND<10)*	ND/78/50*(ND/40)*

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
5409	Benzene	2.4	2
(Fly Ash)	Carbon Tetrachloride	D < 1	-----
	Chloroform	1.4	-----
	1,2-Dichlorobenzene	5.3	-----
	Ethylbenzene	-----	D < 1
	Toluene	2	3.5
	Trichloroethylene	D < 4	-----
	Antimony, Total	3	6
	Beryllium, Total	ND < 0.5	2.5
	Cadmium, Total	1.4	1.0
	Chromium, Total	ND < 2	4
	Copper, Total	27	80
	Cyanide, Totl	15,000	22
	Lead, Total	8	ND < 3
	Nickel, Total	1.7	9.5
	Selenium, Total	2.0	3.0
	Silver, Total	1.6	5.5
	Thallium, Total	1	ND < 1
	Zinc, Total	15	300
	Total Suspended Solids	5	15,000
	Total Organic Carbon	D < 20,000	7,600
	Chloride	-----	37,000
	Vanadium, Total	13	27
	1,3 and 1,4-Dichlorobenzene	2.4	2.4

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
2603 (Combined Fly Ash and Bottom Ash Pond)	Benzene	D < 10	D < 10
	Chloroform	D < 10	D < 10
	1,1-Dichloroethylene	ND	D < 10
	Ethylbenzene	ND	D < 10
	Methylene Chloride	D < 10	10
	Phenol (GC/MS)	ND/9*	ND/4*
	Bis(2-Ethylhexyl)Phthalate	D < 10	D < 10
	Butyl Benzyl Phthalate	D < 10	ND
	Di-N-Butyl Phthalate	D < 10	D < 10
	Diethyl Phthalate	50	10
	Dimethyl Phthalate	ND	D < 10
	Tetrachloroethylene	D < 10	ND
	Antimony, Total	ND < 2	10
	Arsenic, Total	ND < 20	300
	Cadmium, Total	ND < 2	3
	Chromium, Total	10	12
	Copper, Total	22	10
	Mercury, Total	0.2	-----
	Nickel, Total	8	10
	Selenium, Total	ND < 2	13
	Silver, Total	ND < 1	4
	Zinc, Total	88	ND < 60
	Total Dissolved Solids	292,000	455,000
	Total Suspended Solids	-----	D < 5000
	Oil and Grease	-----	1,000
	Total Organic Carbon	9,000	6,000
	Aluminum, Total	497	131

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
2603 (Cont'd)	Barium, Total	17	92
	Boron, Total	ND < 50	209
	Calcium, Total	48,700	62,100
	Manganese, Total	65	10
	Magnesium, Total	15,300	15,500
	Molybdenum, Total	ND < 5	143
	Sodium, Total	23,600	32,000
	Tin, Total	36	36
	Titanium, Total	18	ND < 15
	Iron, Total	842	170
	Vanadium, Total	-----	22
5604 (Combined Fly Ash)	Benzene	1.2	2.0
	Ethylbenzene	-----	D < 1
	Toluene	9.1	3.5
	Antimony, Total	4	6
	Beryllium, Total	ND < 0.5	2.5
	Cadmium, Total	ND < 0.5	1.0
	Chromium, Total	ND < 2	4
	Copper, Total	700	80
	Cyanide, Total	4	22
	Lead, Total	6	ND < 3
	Mercury, Total	ND < 0.2	0.2
	Nickel, Total	ND < 0.5	9.5
	Silver, Total	ND < 3	5.5
	Zinc, Total	53	300
	Total Suspended Solids	-----	15,000
	Total Organic Carbon	5,500	7,600
	Chloride	14,000	37,000
	Vanadium, Total	11	27

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
3920	Beryllium, Total (Dissolved)	ND (ND)	2(2)
(Fly Ash)	Chromium, Total (Dissolved)	20/2*(10/ND<5)*	50/9*(41/8)*
	Copper, Total (Dissolved)	ND<6/8(4/ND<6)*	ND/30*(ND/40)*
	Lead, Total (Dissolved)	20/ND<20*(18/40)*	8/ND<20*(14/30)*
	Nickel, Total (Dissolved)	25/ND<3*(14/ND<5)*	16/20*(ND<9/40)*
	Zinc, Total (Dissolved)	ND/ND<60*(ND/ND<60)*	180/100*(ND/200)*
	Total Dissolved Solids	220,000	880,000
	Total Suspended Solids	12,000	73,000
	Total Organic Carbon	5,000	3,000
	Aluminum, Total (Dissolved)	ND<50(ND<50)	5,000(6,000)
	Barium, Total (Dissolved)	30(30)	60(ND<5)
	Boron, Total (Dissolved)	80(90)	1,000(5,000)
	Calcium, Total (Dissolved)	28,000(27,000)	120,000(120,000)
	Cobalt, Total (Dissolved)	ND<5(ND<5)	7(7)
	Manganese, Total (Dissolved)	50(50)	300(500)
	Magnesium, Total (Dissolved)	7,200(7,400)	6,700(9,700)
	Molybdenum, Total (Dissolved)	ND<5(6)	10(8)
	Phenolics, 4AAP	40	40
	Sodium, Total (Dissolved)	18,000(17,000)	35,000(47,000)
	Iron, Total	500	2,000
	Cadmium (Dissolved)	(ND<3)	(10)
	Silver (Dissolved0	(ND/ND)*	(ND/5)*
	Tin (Dissolved)	(20)	(20)

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
3924 (Fly Ash)	Chromium, Total (Dissolved)	7/ND<5*(ND/ND<5)*	27/70*(49/ND<5)*
	Copper, Total (Dissolved)	18/10*(16/9)*	32/ND<6*(42/ND<6)*
	Lead, Total (Dissolved)	10/ND<20*(5/ND<20)*	23/ND<20*(1/ND<20)*
	Nickel, Total (Dissolved)	18/ND<5*(ND/ND<5)*	23/40*(10/6)*
	Zinc, Total (Dissolved)	20/ND<60*(20/ND<60)*	20/ND<60*(ND/ND<60)*
	Total Dissolved Solids	480,000	670,000
	Total Suspended Solids	15,000	16,000
	Total Organic Carbon	21,000	16,000
	Barium, Total (Dissolved)	40(40)	200(200)
	Boron, Total (Dissolved)	100(100)	1,000(4,000)
	Calcium, Total (Dissolved)	57,000(55,000)	110,000(110,000)
	Manganese, Total (Dissolved)	100(50)	80(70)
	Magnesium, Total (Dissolved)	13,000(14,000)	14,000(14,000)
	Molybdenum, Total (Dissolved)	ND<5(ND<5)	300(300)
	Phenolics, 4AAP	38	35
	Sodium, Total (Dissolved)	43,000(44,000)	38,000(39,000)
	Iron, Total	500	300
	Aluminum (Dissolved)	ND < 50	60
	Tin (Dissolved)	(20)	(ND<5)
3001 (Combined Fly Ash and Bottom Ash Pond)	Chromium, Total (Dissolved)	ND/10*(ND/10)*	190/ND*(93/40)*
	Copper, Total (Dissolved)	ND/10*(22/ND<6)	ND/ND<6*(20/ND<6)*
	Lead, Total (Dissolved)	ND/ND<20*(ND/ND<20)*	3/ND<20*(4/ND<20)*
	Nickel, Total (Dissolved)	ND/6*(ND/ND<5)*	35/ND<5*(33/ND<5)*
	Total Dissolved Solids	532,000	490,000
	Total Suspended Solids	170,000	30,000
	Oil and Grease	25,000	24,000
	Aluminum, Total (Dissolved)	500(ND<50)	2,000(200)

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
3001 (Cont'd)	Barium Total (Dissolved)	40(60)	200(80)
	Boron, Total (Dissolved)	60(200)	2,000(2,000)
	Calcium, Total (Dissolved)	38,000(48,000)	64,000(38,000)
	Manganese, Total	40	ND < 5
	Cadmium (Dissolved)	ND < 2	8
	Magnesium, Total (Dissolved)	23,000(27,000)	11,000(11,000)
	Molybdenum, Total (Dissolved)	ND < 5(ND<5)	30(20)
	Phenolics, 4AAP	-----	14
	Sodium, Total (Dissolved)	57,000(66,000)	70,000(69,000)
	Tin, Total (Dissolved)	ND < 5(20)	7(20)
	Iron, Total	200	ND < 200
	Vanadium, Total	ND/ND<10*	ND/20*
	1,1,2,2-Tetrachloroethane	24	-----
	Zinc (Dissolved)	(ND/ND<60)*	(20/ND<60)*
5410 (Combined Fly Ash and Bottom Ash Pond)	Cadmium, Total (Dissolved)	9(6)	4(ND<2)
	Chromium, Total (Dissolved)	7/70*(9/7)*	16/100*(ND/ND<5)*
	Copper, Total (Dissolved)	15/6*(9/ND<6)*	29/20*(61/10)*
	Lead, Total (Dissolved)	17/ND<20*(9/ND<20)*	ND/40(ND/ND<20)*
	Nickel, Total (Dissolved)	22/30*(9/6)*	66/100*(43/30)*
	Silver, Total (Dissolved)	ND/ND<1*(ND/2)*	ND/6*(ND/2)*
	Zinc, Total	20/ND<60*(ND/ND<60)*	40/ND<60*(30/ND<60)*
	Total Dissolved Solids	200,000	300,000
	Total Suspended Solids	9,000	20,000
	Total Organic Carbon	9,000	8,000
	Aluminum, Total	ND < 50	800
	Barium, Total (Dissolved)	30(30)	40(30)
	Boron, Total (Dissolved)	60(70)	100(300)

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-41 (Continued)

SUMMARY OF DATA FROM THE VERIFICATION PROGRAM AND EPA SURVEILLANCE AND ANALYSIS REPORTS FOR ASH POND OVERFLOW

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
5410 (Cont'd)	Calcium, Total (Dissolved)	27,000(27,000)	40,000(38,000)
	Cobalt, Total	ND < 5	20
	Manganese, Total (Dissolved)	40(ND<5)	100(200)
	Magnesium, Total (Dissolved)	7,700(7,300)	9,100(8,200)
	Molybdenum, Total	ND < 5	8
	Phenolics, 4AAP	9	6
	Sodium, Total (Dissolved)	18,000(17,000)	22,000(24,000)
	Tin, Total (Dissolved)	10(ND<5)	10(6)
	Titanium, Total	ND < 20	50
	Iron, Total	400	2,000
	Vanadium, Total	ND/ND<10*	ND/10*
	Yttrium, Total	ND < 20	20
	Arsenic (Dissolved)	ND	14
4203 (Combined Fly Ash and Bottom Ash Pond)	1,1,1-Trichloroethane	0.68	-----
	Chloroform	0.17	0.25
	Methylene Chloride	-----	32
	Pentachlorophenol	3.8	6.5
	Tetrachloroethylene	0.4	-----
	Trichloroethylene	0.57	-----
	4,4'-DDD (P.P'-TDE)	D < 0.1	-----
	Arsenic, Total	2	-----
	Cadmium, Total	4	ND < 2
	Chromium, Total	3	13
	Copper, Total	8	8
	Lead, Total	1.7	1.2
	Nickel, Total	18	24
	Selenium, Total	3	ND < 1
	Silver, Total	ND < 2	2
	Zinc, Total	32	15
	Iron, Total	1,100	1,200

*These multiple results represent analyses by multiple analytical labs.
()Values in parentheses indicate dissolved fractions.

Table V-42

CONDITIONS UNDER WHICH ARSENIC IN ASH POND OVERFLOW EXCEEDS 0.05 mg/l (19)

(mg/l)

Plant Code	Plant Capacity	Fuel*	pH	TSS	As	Cu	Cr	Cd	Ni	Fe	Pb	Hg	Zn	Se	Oil and Grease	No. of Samples
3711	781	c/o	6.48	24.5	0.06	0.1	0.05	0.02	0.1	0.36	0.1	0.002	0.14	0.007	0.23	18
3708	466	c/o	8.48	14.7	0.14	0.1	0.05	0.02	0.1	0.14	0.1	0.003	0.01	0.005	0.16	6
0512	1341	c	8.29	16.5	0.19	0.01	0.01	-	0.01	0.63	0.14	0.001	0.04	0.011	4.0	7
3710	290	c/o	9.07	127	0.416	0.12	0.05	0.02	0.1	0.3	0.1	0.0023	0.11	0.05	0.13	3
4218	1163	c/o	6.63	36.8	0.131	0.075	0.002	-	0.038	0.74	0.002	0.0005	0.087	-	0.9	1
3701	421	c/o	-	18.0	0.09	0.05	0.05	0.01	0.05	0.47	0.05	0.001	0.05	0.10	1.0	3
2103	694	c	8.4	20	0.21	0.15	0.005	-	0.005	0.52	0.007	0.0001	0.02	0.01	0.79	3
3805	660	c	-	15	0.06	0.11	0.02	0.002	-	-	0.01	0.0001	0.04	-	-	1

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*c - coal
o - oil

Table V-43

ARSENIC CONCENTRATIONS IN ASH POND EFFLUENTS (23, 24)

Station Location	Size (MW)	Ash Pond Type	Effluent Concentrations (ppb)[a]	Plant Water Intake Conc. (ppb)	Data Sources
Western W. Virginia	NA	Bottom	<5	NA	23
Eastern Ohio	NA	Bottom	7	NA	23
Southern Ohio	NA	Bottom	<5	NA	23
Eastern Michigan	NA	Bottom	30	NA	23
Southeast Michigan	NA	Fly	40	NA	23
Southeast Ohio	NA	Fly	200	NA	23
Eastern Missouri	NA	Bottom	20	NA	23
Central Utah	NA	Bottom	<5	NA	23
Western W. Virginia	NA	Fly	8	NA	23
Southern Ohio	NA	Fly	10	NA	23
Wyoming	750	Combined	<1	<1	24
Florida	948	Combined	9	3	24
Upper Appalachia	2900	Combined	74	<1	24

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[a] Detection limit for NUS is 5 ppb/for Radian, 1 ppb.

NA - Not Available

LOW VOLUME WASTES

Low volume wastes include boiler blowdown, waste streams from water treatement, and effluent from floor and yard drains.

Boiler Blowdown

Power-plant boilers are either of the once-through or drum-type design. Once-through designs are used almost exclusively in high-pressure, supercritical boilers and have no wastewater streams directly associated with their operation. Drum-type boilers, on the other hand, operate at subcritical conditions where steam generated in the drum-type units is in equilibrium with boiler water. Boiler water impurities are, therefore, concentrated in the liquid phase. The concentration of impurities in drum-type boilers must not exceed certain limitations which are primarily a function of boiler operating conditions. Table V-44 presents recommended limits of total (dissolved and suspended) solids in drum-type boilers as a function of drum pressure (25). Boiler blowdown, therefore, serves to maintain specified limitations for dissolved and suspended solids. In response to the 308 questionnaire, 544 powerplants out of a total 794 indicated presence of boiler blowdown at their facilities.

The sources of impurities in the blowdown are the intake water, internal corrosion of the boiler, and chemicals added to the boiler system. Impurities contributed by the intake water are usually soluable inorganic species (Na^+, K^+, Cl^-, $So_4{}^2$, etc.) and precipitates containing calcium/magnesium cations. Products of boiler corrosion are soluble and insoluble species of iron, copper, and other metals. A number of chemicals are added to the boiler feedwater to control scale formation, corrosion, pH, and solids deposition. A summary of types of chemicals used for these purposes is presented in table V-45. In addition, the following proprietary chemicals which may contribute chromium, copper, and phenol species to the boiler blowdown were identified:

NALCO 37 - contains chromium
NALCO 75 - contains phenol
NALCO 425L - contains copper
CALGON CL35 - contains sodium dichromate.

The boiler blowdown is usually of high quality and even may be of higher quality than the intake water. It is usually suitable for internal reuse in the powerplant, for example, as cooling water makeup (26, 27). Table V-46 presents a statistical analysis of regional EPA data on the quality of boiler blowdown. It should be noted that mean concentrations of phosphorous are computed on the basis of 19 data points. Phosphorous is evidently contributed by phosphate-containing chemicals used for solids deposition control. Under certain conditions, the concentrations of corrosion products such as copper and iron may be high. One power company in Southern California reported maximum concentrations of copper and iron as 2 and 20 ppm,

Table V-44

RECOMMENDED LIMITS OF TOTAL SOLIDS IN BOILER WATER FOR DRUM BOILERS (25)

Drum Pressure (atm)	Drum Pressure (psi)	Total Solids (mg/l)
0-24.4	0-300	3500
20.41-30.5	301-450	3000
30.51-40.8	451-600	2500
40.18-51.0	601-750	2000
51.01-61.0	751-900	1500
61.01-68.0	901-1000	1250
68.01-102.0	1001-1500	1000
102-01-136	1501-2000	750
>136	>2000	15

Table V-45

CHEMICAL ADDITIVES COMMONLY ASSOCIATED WITH INTERNAL BOILER TREATMENT (25)

Control Objective	Candidate Chemical Additives	Residual Concentration in Boiler Water
Scale	di- and tri-sodium phosphates	3-60 mg/l as PO_4^-
	Ethylene diaminetetracetic acid (EDTA)	20-100 mg/l
	Nitrilotriacetic acid (NTA)	10-60 mg/l
	Alginates Polyacrylates Polymethacrylates	up to 50-100 mg/l
Corrosion	Sodium sulfite and catalyzed Sodium sulfite	less than 200 mg/l
	Hydrazine Morpholine	5-45 mg/l
pH	Sodium hydroxide Sodium carbonate Ammonia Morpholine Hydrazine	added to adjust boiler water pH to the desired level, typically 8.0 - 11.0
Solids Deposition	Tannins Lignin derivitives	≤200 mg/l
	Starch Alginates Polyacrylamides Polyacrylates Polymethacrylates Phosphates	20-50 mg/l

Table V-46

STATISTICAL ANALYSIS OF BOILER BLOWDOWN CHARACTERISTICS

(Discharge Monitoring Data - EPA Regional Offices)

Pollutants	Number of Points	Mean Concentration (mg/l)	Log. Mean	Standard Deviation	Log. Deviation
Copper	258	.14	2.9615	.2888	1.2845
Iron	273	.53	2.3486	2.0609	1.6351
Oil & Grease	151	1.74	.0276	4.5311	.9807
Phosphorous	19	17.07	1.8363	12.5154	2.3911
Suspended	230	66.26	1.2198	500.3967	1.9421

respectively. These high values were observed *immediately after* boiler chemical cleaning (26).

Boiler blowdown may be discharged either intermittently or continuously. Table V-47 contains a statistical analysis of flow rates reported in the 308 responses from industry.

Three plants were sampled for boiler blowdown during the verification phase of the sampling program. The results are summarized in Table V-48. Pollutants not listed were not detected.

Water Treatment

Boiler feedwater is treated for the removal of suspended and dissolved solids to prevent scale formation. The water treating processes include clarification, filtration, lime/lime soda softening, ion exchange, reverse osmosis, and evaporation.

Clarification

Clarification is the process of agglomerating the solids in a stream and separating them by settling. The solids are coagulated, by physical and chemical processes, to form larger particles and then allowed to settle. Clarified water is drawn off and may be filtered to remove any traces of turbidity (1). Chemicals commonly added to the clarification process are listed in table V-49. As the table shows, none of these chemicals contain any of the 129 priority pollutants. Table V-50 presents a statistical analysis of clarifier blowdown flow rates reported by the industry in response to the 308 questionnaires. Table V-51 presents a statistical analysis of filter backwash flow rates reported by the industry in response to the 308 questionnaires.

Ion Exchange

Ion exchange processes can be designed to remove all mineral salts in a one-unit operation and, as such, is the most common means of treating supply water. The ion exchange material is an organic resinous material manufactured in bead form. The resin may be one of two types: cation or anion. The ion exchange process generally occurs in a fixed bed of the resin beads which are electrically charged. The beads attract chemical ions of opposite charge. Once all of the available sites on the resin beads have been exhausted, the bed must be regenerated. During regeneration, the bed is backwashed (the normal flow throughout the bed is reversed), causing the bed to erupt and the solids to be released. A regenerant solution is then passed over the resin bed, for approximately 30 minutes for cation resins and 90 minutes for anion resins. The bed is then rinsed with water to wash the remaining voids within the bed.

The resulting exchange wastes are generally acidic or alkaline with the exception of sodium chloride solutions which are neutral. While these wastes do not have significant amounts of suspended solids,

Table V-47

BOILER BLOWDOWN FLOWRATES

(308 questionnaire data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	**coal***					
Flow:	GPD/plant	231	33,259	71,682	0.11	650,000
	GPD/MW	230	148	392	-	3,717
Fuel:	**gas***					
Flow:	GPD/plant	189	19,346	60,933	4	700,000
	GPD/MW	189	163	669	0.08	8,470
Fuel:	**oil***					
Flow:	GPD/plant	148	66,173	320,106	2.7	3,810,000
	GPD/MW	148	287	1,237	0.12	14,066

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Table V-48

SURVEILLANCE AND ANALYSIS DATA FOR BOILER BLOWDOWN

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1003	Chloroform	68	ND
	Dichlorobromomethane	23	ND
	Chlorodibromomethane	3.8	ND
	Arsenic, Total	3	2
	Copper, Total	9	8
	Mercury, Total	1	-----
	Zinc, Total	104	10
	Total Dissolved Solids	207,000	100,000
	Total Suspended Solids	2,800	800
	Oil and Grease	-----	5,000
	Total Organic Carbon	2,280	1,250
	Phenolics, 4AAP	D < 20	D < 20
4203	1,1,2-Trichloroethane	0.23	ND
	Chloroform	4.4	0.12
	Bromoform	0.07	ND
	Dichlorobromomethane	0.87	ND
	Chlorodibromomethane	0.17	ND
	Phenol, GC/MS	4.2	6.4
	Trichloroethylene	0.13	ND
	Antimony, Total	ND < 1	6
	Arsenic, Total	2	2
	Cadmium, Total	4	5
	Copper, Total	22	520
	Lead, Total	ND < 20	40
	Mercury, Total	1.5	1.7
	Zinc, Total	10	68
	Iron, Total	10	60

Table V-48 (Continued)

SURVEILLANCE AND ANALYSIS DATA FOR BOILER BLOWDOWN

Plant Code	Pollutant	Concentration (ppb) Intake	Concentration (ppb) Discharge
2603 Unit #1	Benzene	D < 10	290
	1,1,1-Trichloroethane	ND	D < 10
	1,1,2,2-Tetrachloroethane	ND	D < 10
	Chloroform	D < 10	D < 10
	1,1-Dichloroethylene	ND	60
	Ethylbenzene	ND	D < 10
	Methylene Chloride	D < 10	910
	Phenol, GC/MS	ND/9	ND/15
	Bis(2-Ethylhexyl) Phthalate	D < 10	D < 10
	Butyl Benzyl Phthalate	D < 10	ND
	Di-N-Butyl Phthalate	D < 10	D < 10
	Diethyl Phthalate	50	D < 10
	Tetrachloroethylene	D < 10	D < 10
	Toluene	ND	D < 10
	Trichloroethylene	D < 10	ND
	Antimony, Total	ND < 2	10
	Chromium, Total	10	6
	Copper, Total	22	26
	Lead, Total	ND < 20	36
	Mercury, Total	0.2	ND < 0.1
	Nickel, Total	8	1.3
	Selenium, Total	ND < 2	5.7
	Zinc, Total	88	72
	Total Dissolved Solids	292,000	11,000
	Total Suspended Solids	-----	D < 5,000
	Total Organic Carbon	9,000	D < 3,000
	Calcium, Total	48,700	D < 5,000
	Manganese, Total	65	ND < 5
	Magnesium, Total	15,300	ND < 1,000

Table V-48 (Continued)

SURVEILLANCE AND ANALYSIS DATA FOR BOILER BLOWDOWN

Plant Code	Pollutant	Concentration (ppb) Intake	Concentration (ppb) Discharge
2603	Molybdenum, Total	ND < 5	61
Unit #1	Sodium, Total	-----	D < 15,000
(Cont'd)	Titanium, Total	18	ND < 5
	Iron, Total	842	-----
2603*	Benzene		30
Unit #2	1,1-Dichloroethylene		D < 10
	1,3-Dichloropropene		D < 10
	Ethylbenzene		D < 10
	Methylene Chloride		30
	Bromoform		D < 10
	Phenol, GC/MS		ND/10
	Di-N-Butyl Phthalate		D < 10
	Diethyl Phthalate		D < 10
	Tetrachloroethylene		D < 10
	Toluene		D < 10
	Antimony, Total		20
	Copper, Total		8
	Total Dissolved Solids		7,000
	Total Suspended Solids		D < 5,000
	Total Organic Carbon		3,000
	Aluminum, Total		213
	Calcium, Total		D < 5,000
	Molybdenum, Total		55
	Sodium, Total		D < 15,000

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*Intake data for Plant 2603, Unit #2 is the same as that for Plant 2603, Unit #1.

Table V-49

COAGULATING AND FLOCCULATING AGENT CHARACTERISTICS (25)

Coagulant/Flocculant	Purpose	Normal Dosage (mg/l)
Alum $Al_2(SO_4)_3 \bullet 14\ H_2O$	Main Coagulant To assist coagulation with aluminate	5-50 2-20
Aluminate $Na_2Al_2O_4$	Main Coagulant To assist coagulation with alum	5-15 (0.1 to 0.5 of alum dosage)
Ferric Chloride $FeCl_2 \bullet 6\ H_2O$	Main Coagulant	5-50
Copperas $FeSO_4 \bullet 7\ H_2O$	Main Coagulant	5-50
Weighting Agents (bentenite, kaolin, montmorillonite)	Coagulant Aid	-----
Absorbents (powdered carbon, activated alumina)	Coagulant Aid	-----
Polyelectrolytes (inorganic activated silica and organic polymers)	Coagulant Aid	≤ 2

Table V-50

CLARIFIER BLOWDOWN FLOWRATES

(308 questionnaire data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	coal*					
Flow:	gpd/plant	88	29,966	74,518.4	7	605,000
	gpd/MW	87	64.8	200.9	0.04	1,208
Fuel:	gas					
Flow:	gpd/plant	26	57,653	234,909	10	1,200,000
	gpd/MW	26	210.8	914	0.11	4,678
Fuel:	oil					
Flow:	gpd/plant	14	19,779	29,820	20	100,420
	gpd/MW	14	107.9	196.8	0.15	697

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Table V-51

FILTER BACKWASH FLOWRATES

(308 questionnaire data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	**coal***					
Flow:	gpd/plant	155	25,460	42,027	1.6	300,000
	gpd/MW	154	71	258	0.013	2,400
Fuel:	**gas***					
Flow:	gpd/plant	58	7,827	15,153	40	94,200
	gpd/MW	58	41	87	0.1	404
Fuel:	**oil***					
Flow:	gpd/plant	58	25,003	58,410	30	250,000
	gpd/MW	58	168	677	0.13	4,528

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation in the year 1975.

certain chemicals such as calcium sulfate and calcium carbonate have extremely low solubilities and are often precipitated because of common ion effects.

The wastes may be collected in an equalization tank or basin and neutralized with acid or alkali or slowly mixed with other nonprocess wastes prior to treatment. In the cases where the wastes are mixed with other non-process water, there may be the effect of neutralization by the natural alkalinity or acidity of the non-process stream. In any of the treatment cases discussed above, the treated water is suitable for reuse as non-process makeup water.

Spent regenerant solutions, constituting a significant part of the total flow of wastewater from ion exchange regeneration, contains ions which are eluted from the ion exchange material plus the excess regenerant that is not consumed during regeneration. The eluted ions represent the chemical species which were removed from water during the service cycle of the process. Table V-52 presents a summary of ion exchange material types and regenerant requirements of each. Historical raw waste load data for ion exchange regenerant is shown in table V-53. Table V-54 contains a statistical analysis of ion exchange spent regenerant flow rates reported in the industry response to the 308 questionnaire.

Lime/Lime Soda Softening

In lime softening, chemical precipitation is applied to hardness and alkalinity. Calcium precipitates as calcium carbonate ($CaCO_3$) and magnesium as magnesium hydroxide ($Mg(OH)_2$). The softening may take place at ambient temperatures, known as cold process softening, or at elevated temperatures (100 C or 212 F), known as hot process softening (1). The hot process accelerates the formation of the carbonates and hydroxides. Hot process softening is commonly employed for treating boiler feed water in facilities where steam is generated for heating processes as well as electric power generation. Since lime and/or soda ash are the only chemicals added in this process, none of the priority pollutants will be introduced in the system. Table V-55 presents a statistical analysis of lime softener blowdown flow rates reported by the industry in response to the 308 questionnaires.

Evaporator Blowdown

Evaporation is a process of purifying water by vaporizing it with a heat source and condensing the vaporized water. The influent water evaporates and is ducted to an external product condenser. In the lower portion of the evaporator, a pool of boiling water is maintained at a constant level to keep the heat source (steam tubes) immersed in liquid. Water is periodically blown down from the bottom to lower the contaminant levels. Table V-56 presents historical raw waste load data for the evaporator blowdown. As indicated in this table, suspended solids in the blowdown may reach very high levels. Table V-57 presents a statistical analysis of evaporator blowdown flow rates reported by the industry in response to the 308 questionnaires.

Table V-52

ION EXCHANGE MATERIAL TYPES AND REGENERANT REQUIREMENT (25)

Ion Exchange Material	Description of Operation	Regenerant Solution	Regenerant Requirement Theoretical Amount
Cation Exchange Sodium Cycle	Sodium cycle ion exchange is used as a water softening process. Calcium, magnesium, and other divalent cations are exchange for more soluble sodium cations, i.e., $2R_c$ - Na + Ca^{++} $(R_c)_2$ - Ca + 2 NA^+ $2R_c$ - Na _ Hg^{++} (R_c) - Mg + 2 Na^+	10% brine (NaCl) solution or some other solution with a relatively high sodium content such as sea water.	-----
Hydrogen Cycle Weak Acid	Weak acid ion exchange removes cations from water in quantities equivalent to the total alkalinity present in the water, i.e., $2R_c$ - H + $Ca(HCO_3)_2$ (R_c) - Ca + 2 H_2CO_3	H_2SO_4 or HCl solutions with acid strengths as low as 0.5%.	110-120%
Strong Acid	Strong acid ion exchange removes cations of all soluble salts in water, i.e., R_c - H NaCl R_c - Na + HCl	H_2SO_4 or HCl solutions with acid strengths ranging from 2.0-6.0%.	200-400%
Anion Exchange Weak Base	Weak base ion exchange removes anions of all strong mineral acids (H_2SO_4, HCl, HNO_3, etc.), i.e., $2R_A$ - OH + H_2SO_4 $(R_A)_2$ - SO_4 + 2HOH	NaOH, NH_4OH, Na_2CO_3 solutions of variable strength	120-140%
Strong Base	Strong base ion exchange removes anions of all soluble salts in water i.e., R_A - OH + H_2CO_3 R_A - HCO_3 + HOH	NaOH solutions at approximate 4.0% strength.	150-300%

Table V-53

ION EXCHANGE SPENT REGENERANT CHARACTERISTICS

(Discharge Monitoring Data - EPA Regional Offices)

Pollutant	Mean Value	Standard Deviation	Minimum Value	Maximum Value
pH (122 entries)	6.15	2.45	1.7	10.6
Suspended solids (mg/l) (88 entries)	44	60.14	3.0	305
Dissolved solids (mg/l) (39 entries)	6,057	2,435	1,894	9,645
Oil and Grease (mg/l) (29 entries)	6.0	6.7	0.13	22

Table V-54

ION EXCHANGE SOFTENER SPENT REGENERANT FLOWRATES

(308 Questionnaire Data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	coal*					
Flow:	gpd/plant	104	9,290	16,737	14.4	107,143
	gpd/MW	104	79	264	0.12	2,028
Fuel:	gas*					
Flow:	gpd/plant	86	11,142	32,663	7	164,000
	gpd/MW	86	84	247	0.12	2,058
Fuel:	oil*					
Flow:	gpd/plant	42	19,358	32,965	16	132,000
	gpd/MW	42	226	764	0.43	4,633

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation in the year 1975.

Table V-55

LIME SOFTENER BLOWDOWN FLOWRATES

(308 Questionnaire Data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: coal*						
Flow:	gpd/plant	37	26,228	85,069	29	50,000
	gpd/MW	37	56	117	0.28	625
Fuel: gas*						
Flow:	gpd/plant	40	30,937	144,642	15	900,000
	gpd/MW	40	154	558	0.17	3,508
Fuel: oil*						
Flow:	gpd/plant	15	15,808	57,099	75	222,180
	gpd/MW	15	216	818	0.62	3,174

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation in the year 1975.

Table V-56

EVAPORATOR BLOWDOWN CHARACTERISTICS

(Discharge Monitoring Data - EPA Regional Offices)

Pollutants	Number of Points	Mean Concentration (mg/l)	Log. Mean	Standard Deviation	Log. Deviation
Copper	9	.39	-.9671	.0875	.2080
Iron	9	.54	-.6198	.0831	.1543
Oil & Grease	9	2.1	.7085	.4841	.2404
Suspended Solids	31	28.4	2.4499	36.7079	1.5392

Table V-57

EVAPORATOR BLOWDOWN FLOWRATES

(308 Questionnaire Data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	coal*					
Flow:	gpd/plant	104	29,310	96,221	2	962,800
	gpd/MW	104	126	810	-	8,292
Fuel:	gas*					
Flow:	gpd/plant	83	13,647	34,312	8	215,000
	gpd/MW	83	74	222	0.02	1,512
Fuel:	oil*					
Flow:	gpd/plant	57	320,293	2,111,836	15	15,900,000
	gpd/MW	57	4,781	34,796	0.11	262,809

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*Fuel designation are determined by the fuel which contributes the most Btu for power generation in the year 1975

Reverse Osmosis

Reverse osmosis is a process in which a semipermeable membrane--generally cellulose acetate or a polyamide--separates two solutions of different concentrations. In the case of a salt solution, use of a membrane impermeable to salt will allow only water to leave the solution, producing one stream with a greater salt concentration than the feed and one, more dilute. The concentrated stream is called the reverse osmosis brine and constitutes the waste stream from the process. Table V-58 presents a statistical analysis of reverse osmosis brine flow rates reported by the industry in response to the 308 questionnaires. In the water treatment schemes reported by the industry, reverse osmosis was always used in conjunction with demineralizers and sometimes in conjunction with clarification, filtration, and ion exchange softening.

Drains and Spills

Floor and Yard Drains

There are numerous sources of wastewater in the nature of piping and equipment drainage and leakage throughout a steam electric facility. The list in table V-59 is a representative compilation of the sources, showing major contaminants, the likelihood of occurrence, potential severity, and control techniques which might be employed. There have been no data reported for this stream, however, the pollutant parameters which may be of concern would be oil and grease, pH, and suspended solids.

Laboratory Streams

Many steam electric powerplants maintain laboratory facilities to carry out chemical analyses as a part of controlling the operation of the plant. This would include elemental analysis and heating value analysis of coal, analysis of treated boiler water, and boiler tube cleaning chemical analysis.

The wastes from the laboratories vary in quantity and constituents, depending on the use of the facilities and the type of powerplant. The chemicals are usually present in extremely small quantities. It has been common practice to combine laboratory drains with other plant plumbing.

Sampling Results

Demineralizer regenerants were sampled in three facilities during the verification phase of the sampling program. Analytical results are presented in Table V-60.

METAL CLEANING WASTES

Metal cleaning wastes include wastewater from chemical cleaning of boiler tubes, air preheater washwater, and boiler fireside washwater.

Table V-58

REVERSE OSMOSIS BRINE FLOWRATES

(308 Questionnaire Data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	coal*					
Flow:	gpd/plant	3	10,674	18,192	3	31,680
	gpd/MW	3	31	53	0.25	92
Fuel:	gas*					
Flow:	gpd/plant	11	18,179	27,437	465	95,000
	gpd/MW	11	55	42	23	165

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation in the year 1975.

Table V-59

EQUIPMENT DRAINAGE AND LEAKAGE (1)

Source	Major Contaminants	Frequency	Potential Severity	Potential Control Techniques
Oil-water Heat Exchangers	Oil	Remote Possibility	Severe	1. Continuous Gravity Separation 2. Detection and Batch Gravity Separation 3. Detection & Mechanical Separation 4. Maintain pressure of water greater than oil
Oil Tank, Lines & Transformer Rupture	Oil	Remote Possibility	Severe	1. Isolation from Drains 2. Containment of Drainage
Floor Spills	Suspended Solids or Oil	Daily	Slight	1. Plug Floor Drain 2. Route Floor Drainage Through Clarifier & Gravity or Mechanical Separation
Oil Drips and Tank Leakage	Oil	Daily	Slight	1. Isolate from Floor Drains 2. Route to Gravity or Mechanical Separation
Sump Discharges from Service Bldg. & Yard	Oil and Suspended Solids	Often	Slight	1. Isolate and route clarifier and gravity or mechanical separation
Chemical Tank Rupture	Regenerant and cleaning chemicals	Remote Possibility	Severe	1. Containment of Drainage 2. Isolation from Drains 3. Route drains to Ash Pond or Holding Pond for Neutralization
Chemical Tank Leakage	Regenerant and cleaning chemicals	Occasional	Slight	1. Isolate from Floor Drains 2. Route drains to Ash Pond or Holding Pond

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NOTE: Oil Spill Contingency Plans would apply to significant oil releases.

Table V-60

SURVEILLANCE AND ANALYSIS DATA FOR DEMINERALIZER REGENERANT

Plant Code	Pollutant	Concentration (ppb)	
		Intake	Discharge
1003	1,1,1-Trichloroethane	ND	2
	Chloroform	68	1.8
	Bromoform	23	-----
	Dichlorofluoromethane	3.8	-----
	Arsenic, Total	3	-----
	Copper, Total	9	-----
	Mercury, Total	1	-----
	Selenium, Total	1	-----
	Zinc, Total	104	-----
	Total Dissolved Solids	207,000	4,584,000
	Total Suspended Solids	2,800	9,250
	Total Organic Carbon	2,280	4,810
4203	Chlorobenzene	ND	0.67
	1,1,2-Trichloroethane	0.23	0.68
	Chloroform	4.4	38
	1,2-Dichlorobenzene	ND	39
	1,3-Dichlorobenzene	ND	0.3
	1,4-Dichlorobenzene	ND	5.2
	Methylene Chloride	ND	>220
	Bromoform	0.07	ND
	Dichlorobromomethane	0.87	ND
	Chlorodibromomethane	0.17	ND
	Nitrobenzene	ND	81
	Phenol, GC/MS	4.2	3.8
	Di-N-Octyl Phthalate	ND	22
	Trichloroethylene	0.13	0.38
	Arsenic, Total	2	-----
	Cadmium, Total	4	35
	Chromium, Total	ND<2	26

Table V-60 (Continued)

SURVEILLANCE AND ANALYSIS DATA FOR DEMINERALIZER REGENERANT

Plant Code	Pollutant	Concentration (ppb) Intake	Concentration (ppb) Discharge
4203 (Cont'd)	Copper, Total	22	65
	Cyanide, Total	0	0.04
	Lead, Total	ND<20	24
	Mercury, Total	1.5	1.6
	Nickel, Total	ND<20	230
	Silver, Total	ND<2	58
	Zinc, Total	10	54
	Iron, Total	10	5,000
	Acetone	-----	8.7
2603	Benzene	D<10	ND
	Chloroform	ND<10	140
	1,1-Dichloroethylene	ND	D<10
	Methylene Chloride	D<10	60
	Bromoform	ND	D<10
	Dichlorobromomethane	ND	70
	Chlorodibromomethane	ND	30
	Phenol, GC/MS	ND/9	ND/4
	Bis(2-Ethylhexyl) Phthalate	D<10	D<10
	Butyl Benzyl Phthalate	D<10	-----
	Di-N-Butyl Phthalate	D<10	D<10
	Diethyl Phthalate	50	D<10
	Tetrachloroethylene	D<10	D<10
	Trichloroethylene	D<10	ND
	Antimony, Total	ND<2	20
	Cadmium, Total	ND<2	5
	Chromium, Total	10	14
	Copper, Total	22	27
	Cyanide, Total	ND<5	47
	Mercury, Total	0.2	6

Table V-60 (Continued)

SURVEILLANCE AND ANALYSIS DATA FOR DEMINERALIZER REGENERANT

Plant Code	Pollutant	Concentration (ppb) Intake	Concentration (ppb) Discharge
2603	Nickel, Total	8	200
(Cont'd)	Selenium, Total	ND<2	4
	Thallium, Total	ND<20	182
	Zinc, Total	88	ND
	Total Dissolved Solids	292,000	3,010,000
	Total Suspended Solids	-----	17,000
	Total Organic Carbon	9,000	8,000
	Aluminum, Total	497	277
	Barium, Total	17	ND<5
	Boron, Total	ND<50	63
	Calcium, Total	48,700	169,000
	Manganese, Total	65	9
	Magnesium, Total	15,300	17,400
	Molybdenum, Total	ND<5	15
	Sodium, Total	-----	159,000
	Titanium, Total	18	ND<15
	Iron, Total	842	793

Chemical Cleaning of Boiler Tubes

Chemical cleaning is designed to remove scale and corrosion products which accumulate on the boiler tubes in the boiler's steam-side. There are a number of factors affecting the selection of the cleaning method. Among the major factors are:

1. Type of deposit,
2. Type of metals (alloys) cleaned,
3. Type of boiler,
4. Economics,
5. Prior experience,
6. Hazards associated with cleaning agents, and
7. Ease of waste disposal.

Boiler Cleaning Chemicals

Hydrochloric Acid Without Copper Complexer. Hydrochloric acid is the most frequently used boiler tube cleaning chemical. It has the ability to handle a wider range of deposits than any other solvent available today. This ability, combined with its relatively low cost, availability, and the extensive experience associated with its use for boiler cleanings, is the reason for its popularity in the chemical cleaning of utility boilers (28).

Hydrochloric acid, which is usually used in solutions of 5 to 10 percent, forms soluble chlorides with the scale and corrosion products in the boiler tubes. Its strength makes it very effective for removing heavy deposits; however, due to this strength, an inhibitor is mandatory to reduce attack to boiler tube metal. This strength also allows the use of either the soaking or circulation method of boiler cleaning.

The high chloride content makes the use of hydrochloric acid solutions infeasible for austenitic steels due to the potential for chloride stress cracking (29). Hydrochloric acid is highly corrosive. Hydrogen gas will be liberated during cleaning operations. Large amounts of water are required for rinsing.

Hydrochloric Acid With Copper Complexer. Hydrochloric acid with a copper complexer is used in boilers containing copper to prevent the replating of dissolved copper onto steel surfaces during chemical cleaning operations. The two most prominent complexers are Dow Chemical's Thiourea and Halliburton's Curtain II. If a complexer is not used, copper chlorides, formed during cleaning operation, react with boiler tube iron to form soluble iron chlorides while the copper is replated onto the tube surface. Use of a copper complexer interrupts this reaction by complexing the copper (30,31).

Alkaline Degreaser. Alkaline cleaning (flush/boil-out) is commonly employed prior to boiler cleaning to remove oil-based compounds from tube surfaces. These solutions are composed of trisodium phosphate and a surfactant and act to clear away the materials which may interfere with the reactions of the boiler cleaning chemicals and deposits (32, 33).

Ammoniated Citric Acid. Citric acid cleaning solutions are used by a number of utilities for boiler cleaning operations (34). Utilizing the circulation method, this weak acid is usually diluted to a 3 percent solution and ammoniated to a pH of 3.5 for cleaning purposes. This solution is used in a two-stage process. The first stage involves the dissolution of iron oxides. In the second stage, anhydrous ammonia is added to a pH of 9 to 10 and air is bubbled through the solution to dissolve copper deposits. Halliburton markets this as the Citrosolv Process (35). This "one solution" cleaning process affords some advantages due to the minimal cleaning time and water requirements. The hazards associated with this solution are not as great as with other acids due to its lower corrosivity; however, there is potential for hydrogen gas liberation.

Ammoniated EDTA. The most widely known ammoniated EDTA cleaning chemical is produced by Dow Chemical Company and marketed under the name, "Vertan 675." This boiler cleaning agent has been used successfully in a wide variety of boiler cleaning operations. The cleaning involves a one solution, two-stage process. During the first stage, the solution solubilizes iron deposits and chelates the iron solution. In the second stage, the solution is oxidized with air to induce iron chelates from ferric to ferrous and to oxidize copper deposits into solution where the copper is chelated (36).

The most prominent use of this cleaning agent is in circulating boilers which contain copper alloys. It has gained increasing popularity for use in cleaning utility boilers due to its low hazard (no hydrogen gas formation and not highly corrosive) and low water usage (normally only one rinse required).

Ammonical Sodium Bromate. Occasionally, large amounts of copper deposits in boiler tubes cannot be removed with hydrochloric acid due to copper's relative insolubility. When such conditions exist, solutions of ammonia-based oxidizing compounds have been effective. Used in a single separate stage the ammonical sodium bromate step includes the introduction of solutions containing ammonium bromate into the boiler system to rapidly oxidize and dissolve the copper. This stage may be completed pre- or post-acid stage. It has been found to be effective on units which contain large amounts of copper metals (37).

Hydroxyacetic/Formic Acid. The use of hydroxyacetic/formic acid in the chemical cleaning of utility boilers is common. It is used in boilers containing austenitic steels because its low chloride content prevents possible chloride stress corrosion cracking of the austenitic-type alloys. It has also found extensive use in the cleaning operations for once-through supercritical boilers (38). Circulation of this solvent is required in order to keep desired strength in all areas of the boiler system. Hydroxyacetic/formic acid has chelation properties and a high iron pick-up capability, thus it is used on high iron content systems. It is not effective on hardness scales. If water requirements are low, generally only one rinse is required. The corrosiveness of the solvent is not as high as that of inorganic acids, yet there is potential for hydrogen gas release.

Sulfuric Acid. Sulfuric acid has found limited use in boiler cleaning operations. It is not feasible for removal of hardness scales due to the formation of highly insoluble calcium sulfate (39). It has found some use in cases where a high-strength, low-chloride solvent is necessary. As with other acids, potential hazards involve the liberation of hydrogen gas and the chemical's highly corrosive nature. Use of sulfuric acid requires high water usage in order to rinse the boiler sufficiently.

Waste Characteristics

The characteristics of waste streams emanating from the chemical cleaning of utility boilers are similar in many respects. The major constituents consist of boiler metals; i.e., alloy metals used for boiler tubes, hot wells, pumps, etc. Although waste streams from certain cleaning operations which are used to remove certain deposits; i.e., alkaline degreaser to remove oils and organics; do not contain heavy concentrations of metals, the primary purpose of the total boiler cleaning operation (all stages combined) is removal of heat transfer-retarding deposits, which consist mainly of iron oxides resulting from corrosion. This removal of iron is evident in all total boiler cleaning operations through its presence in boiler cleaning wastes.

Copper is the next most prevalent constitutent of boiler cleaning wastes due to wide use as a boiler system metal. Based on information on nearly 2,500 utility boilers, EPA estimates that copper alloys are used in 91 percent of the steam condenser tubes, 85 percent of the highpressure feedwater heater tubes, and 83 percent of the lowpressure feedwater heater tubes (40). Table V-61 shows a few of these alloys and corresponding constituents.

The presence of boiler metal constituents in chemical cleaning wastes is further illustrated by examining the characteristics of wastes emanating from boilers in which admiralty metals were used for steam condenser tubes and low-pressure feedwater heater tubes. Admiralty metal contains aproximately 25 percent zinc.

The wastewaters from a boiler cleaning operation on a boiler containing such an alloy contained 166 mg/l of zinc. The relatively

Table V-61

ALLOYS AND CONSTITUENTS OF BOILER SYSTEMS (41)

(Percent)

Alloy	Constituent				
	Copper	Iron	Nickel	Zinc	Other
Admiralty	71			25	Sn-4
Arsenical Admiralty	71			27	As-0.04
Phosphorized Admiralty	71			27	P-0.1
Brass	65			35	
Aluminum brass	65			30	Al-5
Copper-nickel 90/10	90		10		
Copper-nickel 80/20	80		20		
Copper-nickel 70/30	70		30		
Cupro-nickel (10%)	89	1.0	10		
Cupro-nickel (20%)	79	1.0	20		
Monel	23	3.5	60		Mn-3.5

high value of zinc was due to the presence of zinc in the boiler tube metal (1).

A number of cleaning agents use complexing agents in order to keep dissolved deposits in solution and thus remove them from the boiler system when the solution is drained. Ammoniated solutions of bromate, citrate, and EDTA have been used for this purpose. Ammonia forms a complex with copper while citrate and EDTA chelate iron and other heavy metals. Ammonia is a monodentate complex former since it contains only one ligand. Citrate and EDTA are multidentate complex formers. Multidentate complexes may be referred to as chelates, whereas monodentate complexes are referred to only as complexers (42). These complexes and chelates are stable compounds and pose greater difficulty in treatment.

Other waste constituents present in spent chemical cleaning solutions include wide ranges of pH, high dissolved solids concentrations, and significant oxygen demands (BOD and/or COD). The pH of spent solutions ranges from 2.5 to 11.0 depending on whether acidic or alkaline cleaning agents are employed.

Waste characteristics for the above mentioned cleaning solutions appear in tables V-62 through V-67. A brief description of those wastes by chemical cleaning solvent type follows.

Alkaline Degreaser. Alkaline cleaning is used to remove oil contaminants which may have entered the boiler system. The cleaning solution waste will contain sodium phosphates, and some boiler metals. In some cases, if chelating agents and sodium hydroxide have been added to the original cleaning solution, these materials and related compounds may be present. Volume of waste solutions will exceed two boiler volumes due to intermittent blowdowns and a final rinse with condensate.

Ammoniated Citric Acid. This waste stream consists of a number of complexed boiler metals. Their presence is dependent upon their use in boiler metals alloys. Citrate, a multidentate ligand, is the chelating agent in this solution, while ammonia forms soluble complexes with copper. Various other constituents of this waste stream will include dissolved deposit components and BOD. Waste volume is generally equivalent to two boiler volumes, which includes a rinse.

Ammoniated EDTA. Ammoniated EDTA wastes are alkaline (pH = 9.0 to 10.0) and contain amounts of iron and copper which are present as ferric and cupric chelates. Although this type of cleaning agent is used generally for removal of copper, the copper content will vary in concentration in proportion to the amount of copper used in the boiler system. Similarily, the content of other boiler metals present in the waste will generally be a function of their presence. The volume of waste from this type of cleaning is usually two boiler volumes. One volume consists of the cleaning solution while the second will be rinse water.

Table V-62

WASTE CONSTITUENTS OF AMMONIATED CITRIC ACID SOLUTIONS (48)
(mg/l)

CONSTITUENTS	C-1	C-2	C-3
Silica		40	
Phosphorous		200	
Copper	220	20	8
Iron	8,300	9,800	10,800
Nickel	130		
Zinc	390		

NOTE: (1) The absence of concentration value denotes information is not available.
(2) C-1, C-2, C-3 denote wastes from independent boiler chemical cleaning operations.

Table V-63

WASTE CONSTITUENTS OF AMMONIATED EDTA SOLUTIONS (48)
(mg/l)

CONSTITUENTS	V-1	V-2	V-3	V-4	V-5	V-6	V-7
Waste Volume, million gallons						19,000	
pH, units	9.2	8.8	9.0	9.5	9.5	9.2	10.0
Dissolved Solids						59,549	73,800
Suspended Solids							24
Oil & Grease							41
Silica					93.69		
NH3 - N							5,200
Phosphorous					260.25		
Aluminum					31.23		
Calcium					20.82	45.3	
Chromium					10.41	26.50	11.6
Copper	11,700	30	53	413	124.92	707	0.17
Iron	2,250	4,600	7,900	7,000	8,328	6,867	6,900
Magnesium					20.82	11.12	
Manganese					72.87	49.93	
Nickel					135.33	68.40	11.8
Sodium						371.87	
Zinc					124.92	143.75	79

NOTE: (1) The absence of concentration value denotes information is not available.

(2) V-1 through V-7 denote wastes from independent boiler chemical cleaning operations.

Table V-64

WASTE CONSTITUENTS OF AMMONIACAL SODIUM BROMATE SOLUTIONS (48)
(mg/l)

CONSTITUENTS	AB-1	AB-2	AB-3	AB-4	AB-5	AB-6
Waste Volume, million gallons					0.217	0.165
pH, units		10.5	10.2			
Dissolved Solids			1,015		340	1,400
Suspended Solids			77		8	71
COD					24	120
Oil & Grease					<5	<5
Silica					7.2	14
NH_3 - N					700	2,000
Org. - N					40	<10
NO_2 + NO_3 - N					0.04	0.51
Phosphorous					10	30
Bromide					52	<5
Chloride					60	
Fluoride					1.5	6.1
Aluminum					<0.2	<0.2
Arsenic	307				0.048	<0.005
Barium					<0.1	<0.1
Beryllium					<0.01	<0.01
Cadmium	<0.02				<0.001	<0.001
Calcium			0.0		3.0	0.4

Table V-64 (Continued)

WASTE CONSTITUENTS OF AMMONIACAL SODIUM BROMATE SOLUTIONS (48)
(mg/l)

CONSTITUENTS	AB-1	AB-2	AB-3	AB-4	AB-5	AB-6
Chromium	<0.05		0.0		<0.005	<0.005
Copper	409	750	117	334	100	790
Iron	1.92		0.15	0	1.7	4.9
Lead	0.1				<0.01	<0.01
Magnesium			0.0		2.9	0.67
Manganese			0.01		0.03	0.04
Mercury	14.9				<0.0002	<0.0002
Nickel	255		0.08	0	0.52	2.5
Potassium					70	220
Selenium	23.6				<0.002	<0.002
Silver					<0.01	<0.02
Sodium			59		3.7	15
Tin					<1	<1
Zinc	1.03		0.41	0.5	0.06	0.54

NOTE: (1) The absence of concentration value denotes information is not available.

(2) AB-1 through AB-6 denote wastes from independent boiler chemical cleaning operations.

Table V-65

WASTE CONSTITUENTS OF HYDROCHLORIC ACID WITHOUT COPPER COMPLEXER SOLUTIONS (48)
(mg/l)

CONSTITUENTS	H-1	H-2	H-3	H-4	H-5	H-6	H-7
Waste Volume, million gallons		0.200	0.217	0.099	0.087	0.070	0.090
pH, units		3.3	0.8	0.7	0.7	0.5	0.7
Suspended Solids		57	8	120	18	35	33
COD		9,900	1,200	1,500	1,200	1,900	1,500
TOC		4,600	240	90	1,800	220	120
Oil & Grease		23	<5	11	7.6	20	23
Phenols		0.05	0.065	0.070	0.035	0.020	0.025
Silica		19	66	120	240	31	
NH_3 - N		325	140	80	220	290	150
Org. - N		225	0.06	140	75	10	870
NO_2 + NO_3 - N			0.07	<0.01	<0.01	<0.01	
Phosphorous		1.2	30	50	35	50	45
Sulfate			<1	10	<1	<1	
Aluminum			6.5	6.6	7.0	8.2	
Arsenic		0.008	0.06	0.01	0.03	0.055	0.035
Barium			<0.1	0.4	0.1	0.3	
Beryllium			<0.01	<0.01	<0.01	<0.01	
Cadmium		<0.001	<0.01	0.051	0.032	0.1	<0.001
Calcium		16	42	70	53	64	74

Table V-65 (Continued)

WASTE CONSTITUENTS OF HYDROCHLORIC ACID WITHOUT COPPER COMPLEXER SOLUTIONS (48) (mg/l)

CONSTITUENTS	H-1	H-2	H-3	H-4	H-5	H-6	H-7
Chromium		<0.005	1.5	6	1.1	8.8	<0.005
Copper	43	0.69	2.2	7.6	18	13	47
Iron	1,125	4,200	1,300	3,820	1,420	3,720	2,780
Lead			0.4	3.8	0.86	5.2	<0.01
Magnesium			8.7	6.5	5.7	8.8	
Manganese		19	6.9	29	10	28	22
Mercury			<0.002	<0.002	<0.002	<0.002	
Nickel	150	110	77	260	170	300	150
Potassium			1.4	2.3	1.5	1.8	
Selenium			<0.004	<0.002	<0.002	<0.002	
Silver			0.02	0.02	0.07	0.03	
Sodium			31	74	40	49	
Tin			<1	7.3	<1	2.8	
Zinc	15.8	0.94	5.9	170	34	53	24

NOTE: (1) The absence of concentration value denotes information is not available.

(2) H-1 through H-7 denote wastes from indenpendent boiler chemical cleaning operations.

Table V-66

WASTE CONSTITUENTS OF HYDROCHLORIC ACID WITH COPPER COMPLEXER SOLUTIONS (48) (mg/l)

CONSTITUENTS	HC-1	HC-2	HC-3	HC-4	HC-5	HC-6
Dissolved Solids						30,980
Suspended Solids						2,375
Silica	280	30				
Phosphorous	100	300				
Calcium					980	66.6
Chromium						16.8
Copper	20	460	110	960	270	530
Iron	4,600	1,900	2,100	3,200	6,200	6,470
Manganese						8.16
Nickel	3	410	20	500		267
Sodium						9.2
Zinc		680	10	840		132

NOTE: (1) The absence of concentration values denotes information is not available.

(2) HC-1 through HC-6 denote wastes from independent boiler chemical cleaning operations.

Table V-67

WASTE CONSTITUENTS OF HYDROXYACETIC/FORMIC ACID SOLUTIONS (48)
(mg/l)

CONSTITUENTS	HFA-1	HFA-2	HFA-3	HFA-4
Copper				2
Iron	9,800	3,600	6,300	2,900
Nickel				5
Zinc				8

NOTE: (1) The absence of concentration value denotes information is not available.
(2) HFA-1 through HFA-4 denote wastes from independent boiler chemical cleaning operations.

Ammoniacal Sodium Bromate. Ammoniated sodium bromate *solutions are* used to remove large amounts of copper from boiler systems. Nitrogen compounds will be present in large quantities due to the ammonia. This cleaning step is followed by a rinse which makes the volume of this chemical cleaning waste equivalent to two boiler volumes.

Hydrochloric Acid Without Copper Complexer. These wastes are generally high in total iron contentration (100 mg/l), low in total copper (100 mg/l) and vary with low to medium concentrations of nickel and zinc, depending on boiler metal alloys. Other significant constituents of this type of waste stream consist of solubilized deposit materials, such as calcium, silica, phosphorous, and oil and grease. Some rather low quantities of arsenic, cadmium, chromium, manganese, and tin are also present due to slight acidic attack on boiler metals. The volume of wastes associated with this type of cleaning is generally four times the boiler capacity. This accounts for rinses and neutralization steps in addition to the acid cleaning step.

Hydrochloric Acid With Copper Complexer. The use of the copper complexer implies that copper is present in the system as a boiler metal and therefore must be removed to prevent replating onto steel surfaces. This copper is present as a complex, as are the concentrations of nickel and zinc which are present mainly at moderate levels. As with waste hydrochloric acid solutions without copper complexer, iron concentrations are very high, generally ranging from 2,000 to 6,000 mg/l, while other constituents consist of lower quantities of other boiler metals. Volume of waste associated with this cleaning process is generally four to five boiler volumes due to rinses and neutralization steps.

Hydroxyacetic/Formic Acid. Hydroxyacetic/formic acid has chelating properties which, at times, may enable a 3 percent solution of these mixed acids to exceed a dissolved iron content of 1.3 percent. Other metals generally do not have high concentrations in this waste cleaning solution due to absence in boiler metals. As with most organic solvents, the total volume will be twice the boiler capacity because a rinse must follow the cleaning step. The organic nature of the solvent will also result in elevated BOD levels.

Sulfuric Acid. This boiler cleaning agent is not widely used. The waste characteristics are probably similar to those of hydrochloric acid without copper complexer. Sulfuric acid is a strong acid which may find use in austenitic steels due to its low chloride content. Metal constituents will vary with their use in boiler metals. Volume of the waste, including rinses and neutralizing steps, will approach four to five boiler volumes.

Sampling Results

A boiler cleaning effluent was analyzed for the presence of priority organics. None of the organics met or exceeded the limit of quantification.

Boiler Fireside Washing

Boiler firesides are commonly washed by spraying high-pressure water against boiler tubes while they are still hot. Waste effluents from this washing operation contain an assortment of dissolved and suspended solids. Acid wastes are common for boilers fired with high-sulfur fuels. Sulfur oxides absorb onto fireside deposits, causing low pH and a high sulfate content in the waste effluent (25). Table V-68 presents average and maximum concentrations of pollutants in fireside washes from Plant 3306 (43). Table V-69 shows historical waste load data for boiler fireside wash waters. Table V-70 presents a statistical analysis of fireside wash flow rates reported by the industry. The daily average flow was computed by multiplying the frequency of cleaning per year times the volume per cleaning and dividing the product by 365.

Air Preheater Washing

Air preheaters employed in power stations are either the tubular or regenerative types. Both are periodically washed to remove deposits which accumulate. The frequency of washing is typically once per month; however, frequency variations ranging from 4 to 180 washings per year are reported (1). Many air preheaters are sectionalized so that heat transfer areas may be isolated and washed without shutdown of the entire unit (25). Higher wash frequencies are expected for air preheaters employing this design feature.

Fossil fuels with significant sulfur content will produce sulfur oxides which adsorb on air preheater deposits. Water washing of these deposits produces an acidic effluent. Alkaline reagents are often added to wash water to neutralize acidity, prevent corrosion of metallic surfaces, and maintain an alkaline pH. Alkaline reagents might include soda ash (Na_2CO_3), caustic soda (NaOH), phosphates, and/or detergent. Preheater wash water contains suspended and dissolved solids which include sulfates hardness, and heavy metals, including copper, iron, nickel, and chromium (1, 25). Waste characteristics data for these waste waters are presented in table V-71. In table V-72, the EPA raw waste load data for air preheater wash water is shown. Table V-73 presents a statistical analysis of air preheater wash flow rates reported by the industry in response to the 308 questionnaire.

COAL PILE RUNOFF

In order to ensure a consistent supply of coal for steam generation, plants typically maintain an outdoor reserve. A 90-day supply is generally maintained to provide a sufficient safety factor. This correlates to approximately 600 to 1,800 m^3 (780 to 2,340 $yards^3$) of stored coal per megawatt of required capacity (1,20). Four factors which may preclude maintaining a large coal reserve are (20):

1. Cost of land required for storage,

Table V-68

AVERAGE AND MAXIMUM CONCENTRATIONS AND LOADING IN RAW WASTEWATER FROM FIRESIDE WASHES AT PLANT 3306 (43)

Constituent	Concentration (mg/l)	Loading (kg/cleaning)
Total chromium	15 max., 1.5 ave.	6.8 ave. (15 lb)
Hexavalent chromium	<1.0 max., 0.02 ave.	0.09 ave. (0.2 lb)
Zinc	40 max., 4.0 ave.	18 ave. (40 lb)
Nickel	900 max., 70 ave.	317 ave. (700 lb)
Copper	250 max., 6.0 ave.	27 ave. (60 lb)
Aluminum	21 max., 2.0 ave.	9 ave. (20 lb)
Iron	14,000 max., 2,500 ave.	11,340 ave. (25,000 lb)
Manganese	40 max., 3.5 ave.	16 ave. (35 lb)
Sulfate	10,000 max., 1,000 ave.	4,540 ave. (10,000 lb)
TDS	50,000 max., 5,000 ave.	22,680 ave. (50,000 lb)
TSS	25,000 max., 250 ave.	1,135 ave. (2,500 lb)
Oil and Grease	Virtually Absent	

Table V-69

WASTE LOAD DATA FOR BOILER FIRESIDE WASH

(Discharge Monitoring Data - EPA Regional Offices)

(mg/l)

Pollutant	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Suspended solids (7 entries)	15,387	19,905	1,914	49,680
Copper (7 entries)	47.82	46.56	2.02	127.00
Iron (7 entries)	9,630.86	14,699.10	966	40,938

Table V-70

FIRESIDE WASH WATER FLOWRATES

(308 Questionnaire Data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	**coal***					
Flow:	gpd/plant	42	2,658	4,500	2.7	20,295
	gpd/MW	42	2.9	4.6	0.03	19
Fuel:	**gas***					
Flow:	gpd/plant	40	512	662	0.3	2,739
	gpd/MW	40	3.4	7	0.006	38.6
Fuel:	**oil***					
Flow:	gpd/plant	81	3,426	6,058	13.7	35,616
	gpd/MW	81	7	11.8	0.1	70

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation in the year 1975.

Table V-71

AIR PREHEATER WASH WATER (1)
(Plant 3410)

	Case #1	Case #2	Case #3
COD (mg/l)	50	70	60
SS	34	83	29
TDS	733	606	746
Oil	.25	8.5	.25
pH	3.5	3.2	3.3
Cl	18.5	16.6	27
SO_4	2,480	1,920	2,720
Cond.	2,700	2,700	3,250
Hard. ($CaCO_3$)	1,600	1,400	1,460
Ca	37.8	29.4	34.4
Mg	333	257	330
Fe (soluble)	515	335	460
Ni	20.8	18	34.8
Cr	1.45	1.0	1.25
Na	360	375	368
Zn	1.06	1.19	1.45

Table V-72

WASTE LOAD DATA FOR AIR PREHEATER WASH

(Discharge Monitoring Data - EPA Regional Offices)

(mg/l)

Pollutant	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Suspended Solids (78 entries)	1,268.52	1,663.14	40	10,211
Copper (77 entries)	148.03	815.37	0.1	6,000
Iron	1,953.28	2,023.79	0.05	8,250

Table V-73

AIR PREHEATER WASHWATER FLOWRATES

(308 Questionnaire Data)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel:	**Coal***					
Flow:	gpd/plant	148	10,844.4	22,234.04	2.7	156,164.4
	gpd/MW	147	14.5	31.8	0.01	320.2
Fuel:	**Gas***					
Flow:	gpd/plant	56	980.1	1,922.8	0.27	9,863
	gpd/MW	56	3.8	6.2	0.002	25.9
Fuel:	**Oil***					
Flow:	gpd/plant	110	10,666.7	50,872.6	1.4	526,027.4
	gpd/MW	110	17.6	62.2	0.02	618.8

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation in the year 1975.

2. Labor force and equipment required to maintain coal storage area,

3. Cost of larger inventory, and

4. Loss in heating value of coal due to oxidative degradation.

The quantity of runoff is dependent on the amount of rainfall. A correlation developed by TVA to predict the runoff in inches per acre for a given storm event when the total inches of rainfall are known is given in equation 10 (44).

$$\text{Runoff} = 0.855 * \text{Rainfall} + 0.0082 \qquad (10)$$

The following generalizations may be made with regard to emergence of contaminants in coal pile drainage (44):

1. For a coal pile of a given size and configuration, the amount of contaminants generated and flushed depends upon the residence time of the water within the coal pile.

2. The time required to complete the flushing of contaminants from the coal pile depends upon the volume of water applied (hydraulic head) and the duration of the application.

3. Before flushing is complete, concentrations of contaminants are inversely proportional to the flow rate of drainage runoff.

4. Upon completion of flushing, there is no significant change in contaminant levels with changes in flow rate.

The contaminants and their respective amounts can be classified into specific types according to chemical characteristics. The first type relates to pH of the coal pile drainage. The pH tends to be of an acid nature, primarily as a result of the oxidation of iron sulfide in the presence of oxygen and water. The reaction is believed to occur in two steps (20, 44). The products of the first step are ferrous iron and sulfuric acid as shown in equation 11.

$$2FeS_2 + 7O_2 + 2H_2O \rightleftarrows 2FeSO_4 + 2H_4SO_4 \qquad (11)$$

The ferrous iron (Fe^{2+}) then undergoes oxidation to the ferric state (Fe^{3+}) as shown in equation 12.

$$4FeSO_4 + 2H_2SO_4 + O_2 \rightleftarrows 2Fe_2(SO_4)_3 + 2H_4O \qquad (12)$$

The reaction may proceed to form ferric hydroxide or basic ferric sulfate as shown in equations 13 and 14, respectively.

$$Fe_2(SO_4)_3 + 6H_2O \rightleftarrows 2Fe(OH)_3 + 3H_2SO_4 \qquad (13)$$

$$Fe_2(SO_4)_3 + 2H_2O \rightleftarrows 2Fe(OH(SO_4) + H_2SO_4 \qquad (14)$$

The ferric iron can also directly oxidize pyrite to produce more ferrous iron and sulfuric acid as shown in equation 15.

$$FeS_2 + 14Fe^{+3} + 8H_2O \rightleftarrows 15Fe^{+2} + 2SO_4^{-2} + 16H^+ \quad (15)$$

Thus, the oxidation of one mole of iron pyrite yields 2 moles of sulfuric acid.

As the pH of the pyritic systems decreases below 5, certain acidophilic, chemoautotrophic bacteria become active. These bacteria, Thiobacillus ferroxiduns, Ferrobacillus ferroxidans, Metallogenium, and similar species are active at pH 2.0 to 4.5 and use CO_2 as their carbon source (45). These bacteria are responsible for the oxidation of ferrous iron to ferric state, the rate limiting step in the oxidation of pyrite. Their presence is generally an indication of rapid pyrite oxidation and is accompanied by waters low in pH and high in iron, manganese, and total dissolved solids.

The potential influence of pH on the behavior of toxic and heavy metals is of particular concern. Many of the metals are amphoteric with regard to their solubility behavior. The factors affecting acidity, pH and the subsequent leaching of trace metals are (44):

1. Concentration and form of pyritic sulfur in coal;

2. Size of the coal pile;

3. Method of coal preparation and clearing prior to storage;

4. Climatic conditions, including rainfall and temperature;

5. Concentrations of $CaCO_3$ and other neutralizing substances in the coal;

6. Concentration and form of trace metals in the coal; and

7. The residence time in the coal pile.

Table V-74 contains results of analysis of samples from coal piles at two TVA plants. Both facilities exhibited very low pH values; however, the acidity values were quite variable in each of the cases, which demonstrates that acidity is not a measure of hydrogen ion but rather a measure of available protons. The suspended solids levels observed went up to 2,500 mg/l. Elevated levels of total suspended solids result when rainfall/runoff suspends coal fires in the pile. Most of the total dissolved solids concentrations are a consequence of enhanced pyritic oxidation via equations 11-15. Table V-75 displays data on the concentrations of metals in coal pile runoff from two TVA plants. An examination of the data reveals that there is a large degree of variability among the values. The metals present in the greatest concentrations were copper, iron, aluminum, and nickel. Others present in trace amounts include chromium, cadmium, mercury, arsenic, selenium, and berillium.

Table V-74

CHARACTERISTICS OF COAL PILE RUNOFF (44)

Plant		pH	Acidity (mg/l CaCO)	Sulfate (mg/l)	Dissolved Solids (mg/l)	Suspended Solids (mg/l)	Fe (mg/l)	Mn (mg/l)
J	Range	2.3-3.1	300-7100	1800-9600	2500-16000	8.0-2300	240-1800	8.9-45
	Mean	2.79	3400	5160	7900	470	940	28.7
	N	19	18	18	18	18	19	19
E	Range	2.5-3.1	860-2100	1900-4000	2900-5000	38-270	280-480	2.4-10.0
	Mean	2.67	1360	2780	3600	190	380	4.13
	N	6	6	6	6	6	6	6
E*	Range	2.5-2.7	300-1400	870-5500	1200-7500	69-2500	62-380	0.88-5.4
	Mean	2.63	710	2300	2700	650	150	2.3
	N	14	14	14	14	14	14	14

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*Discrete Storm

Table V-75

CONCENTRATIONS OF METALS IN COAL PILE RUNOFF (44)
(mg/l)

Plant		Cu	Zn	Cd	Al	Ni
	Range	0.43-1.4	2.3-16	<.001-<.001	66.0-440	0.74-4.5
J	Mean	0.86	6.68	<.001	260	2.59
	N_D*	0	0	19	0	0
	N^+	19	19	19	19	19
	Range	0.01-0.46	1.1-3.7	<.001-0.003	22.0-60.0	0.24-0.46
E	Mean	0.23	2.18	0.002	43.3	0.33
	N_D*	0	0	2	0	0
	N^+	6	6	6	6	6

		Cr	Hg	As	Se	Be
	Range	<0.005-.011	<.0002-.0025	.005-0.6	<.001-.03	0.03-0.07
J	Mean	.007	.0004	0.17	0.006	0.044
	N_D*	11	12	0	4	0
	N^+	17	20	19	18	18
	Range	<0.005-.011	0.003-.007	0.006-0.046	<.001-.001	<.01-0.03
E	Mean	0.007	0.004	0.02	0.001	0.014
	N_D*	3	0	0	3	3
	N^+	6	5	4	4	4

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*ND = Number of samples.below detection limits.

Wet Flue Gas Cleaning Processes

Flue Gas Desulfurization Systems

In 1977 there were approximately 34 powerplants in the United States having operational FGD systems. In addition, 42 such systems were under construction (49). The breakdown of existing, constructed, and planned FGD systems by the type of process used for desulfurization of the stack gases is given in table V-76.

In all of the existing FGD systems the main task of absorbing SO_2 from the stack gases is accomplished by scrubbing the exiting gases with an alkaline slurry. This may be preceded by partial removal of fly ash from the stack gases. Existing FGD processes may be divided into two categories: nonregenerable (throwaway) and regenerable. Nonregenerable flue gas desulfurization processes include lime, limestone, and lime/limestone combination and double alkali systems. The following is a short description of each process with characterization, where applicable or available, of the liquid wastes generated in the processes.

Nonregenerable Processes

Lime and Limestone Scrubbing Processes. In the lime or limestone flue gas desulfurization process SO_2 is removed from the flue gas by wet scrubbing with a slurry of calcium oxide (lime) or calcium carbonate (limestone). The principal reactions for absorption of SO_2 by slurry are:

$$\text{lime: } SO_2 + CaO + 1/2H_2O \rightleftarrows CaSO_3 \cdot 1/2H_2O$$

$$\text{limestone: } SO_2 + CaCO_3 + 1/2H_2O \rightleftarrows CaSO_3 \cdot 1/2H_2O + CO_2$$

Oxygen absorbed from the flue gas or surrounding atmosphere causes the oxidation of absorbed SO_2. The calcium sulfite formed in the principal reaction and the calcium sulfate formed through oxidation are precipitated as crystals in a holding tank. The crystals are recovered in a solid/liquid separator. Waste solids disposal is accomplished by ponding or landfill. The clear liquid can be recycled.

A bleed stream is taken off the effluent hold tank to be dewatered. This step, necessary to minimize the land area needed for sludge disposal, varies depending on the application and type of disposal.

For systems with on-site pond disposal, solids may be pumped directly from the effluent hold tank to the pond area. Clean overflow liquor from the pond may then be returned to the system. If necessary, a thickening device such as a clarifier or centrifuge can be used to increase the solids content. Additional dewatering to 60-70 percent solids can sometimes be achieved by various systems including vacuum filtration.

Table V-76

SUMMARY OF NEW AND RETROFIT FGD SYSTEMS BY PROCESS (49)

Process Type	New or Retrofit	Operational		Under Construction		Planned		Total No. of Plants	
		No.	MW	No.	MW	No.	MW	No.	MW
Lime	N	4	2,450	10	4,565	0	0	16	8,440
	R	8	1,650	0	0	2	660	10	2,310
Lime/alkaline flyash	N	3	1,170	1	500	1	527	7	3,597
	R	0	0	0	0	3	579	3	579
Lime/limestone	N	0	0	0	0	0	0	0	0
	R	2	20	0	0	0	0	2	20
Limestone	N	8	4,443	23	9,620	5	2,880	45	21,726
	R	3	790	1	425	0	0	5	1,790
Subtotal-lime/limestone	N	15.	8,963.	34.	14,685.	6.	3,407.	68.	33,763.
	R	13.	2,460.	1.	425.	5.	1,239.	20.	4,699.
Aqueous	N	0	0	0	0	0	0	0	0
	R	0	0	0	0	0	0	1	100
Aqueous carbonate/fab. filter	N	0	0	0	0	0	0	1	400
	R	0	0	0	0	0	0	0	0
Double alkali	N	0	0	2	825	0	0	2	825
	R	0	0	1	277	0	0	1	277
Magnesium oxide	N	0	0	0	0	0	0	0	0
	R	1	120	0	0	3	726	4	846
Not selected	N	0	0	0	0	18	9,500	19	9,800
	R	0	0	0	0	4	2,100	4	2,100
Regenerable not selected	N	0	0	0	0	0	0	0	0
	R	0	0	0	0	1	650	1	650
Sodium carbonate	N	1	125	1	509	1	125	3	759
	R	2	250	0	0	0	0	2	250
Wellman Lord	N	0	0	1	500	1	500	2	1,000
	R	0	0	1	180	0	0	1	180
Wellman Lord/Allied Chemical	N	1	375	0	0	0	0	1	375
	R	1	115	1	340	0	0	2	455
TOTALS	N	17.	8,563.	38.	16,519.	26.	13,532.	96.	46,922.
	R	17.	2,945.	4.	1,222.	13.	4,715.	36.	9,557.
Lime/limestone % of total MW	N	94		89		25		72	
	R	84		35		26		49	

NOTES: N - new
R - retrofit

Lime or limestone systems typically recycle overflow water from the thickener or settling pond. If all the overflow is recycled, the system is a closed loop system (no discharge). Many of the lime or limestone systems discharge scrubber waters usually to control dissolved solids levels.

Another source of discharge not common to all systems is the mist elimination wash. This involves the practice of either continuous or intermittent wash of the demister vanes of the scrubber. Scrubber slurry carryover (material carried from the contactor with the flue gas) is retained in the system by impacting the demister section. Cleaning of the demister is then accomplished by washing. The resulting wash water is then either sent to the thickener, recycle tank, or the settling pond. A summary of composition data for a typical demister wash is presented in table V-77.

Double Alkali Wet Scrubbing. A number of processes can be considered double alkali processes. In the United States, most of the developmental work has emphasized sodium-based double alkali systems using lime for regeneration. Double alkali systems using an ammonia/calcium base have been tested, but they suffer the disadvantage of potentially producing a visible ammonium salt plume from the scrubbing system. The following process description will be limited to sodium/calcium-based processes.

Flue gas is pretreated in a venturi or tray type prescrubber to cool and humidify the gas and to reduce fly ash and chlorides. The humidification and cooling step prevents the evaporation of excessive amounts of water in the absorber. The potential for scaling and plugging problems is reduced by the removal of fly ash which, containing vanadium and iron compounds, can catalyze the oxidation of Na_2O_3 to Na_2SO_4.

Cool and humidified gas from the prescrubber passes through an absorption tower, where SO_2 is removed by absorption into a sodium hydroxide or sodium sulfite scrubbing solution. The scrubber effluent liquor is regenerated with lime or limestone in a reaction tank.

The calcium sulfite and calcium sulfate solids formed in the reaction tank were withdrawn from the system in a solid/liquid separator. After make-up alkali and water are added, the separator effluent liquor is recycled to the scrubbing loop. A liquid purge stream is required to remove soluble sodium sulfate. Failure to allow for sulfate removal from double alkali systems will ultimately result in (1) precipitation of sodium sulfate somewhere in the system if active sodium is made up to the system; or (2) in the absence of makeup, eventual deterioration of the SO_2 removal capability due to the loss of active sodium from the system.

Discharges From Non-Regenerable Scrubbing Systems. All the non-regenerable scrubbing systems have a disadvantage in that they produce large amounts of throwaway sludges which may pose problems in disposal. Onsite disposal is usually performed by sending the waste

Table V-77

COMPOSITION OF EFFLUENT FROM ONCE-THROUGH MIST ELIMINATOR WASH UNIT AT WET LIMESTONE SCRUBBER SYSTEM (50)

	Concentration at indicated wash rate		
Water quality parameter	40.7 l/min/m^2	20.35 l/min/m^2	10.18 l/min/m^2
Acidity (methyl orange), as $CaCO_3$, mg/l	49	-	120
Acidity (total), as $CaCO_3$, mg/l	64	-	150
Ammonia nitrogen, mg/l	0.21	0.25	0.34
Calcium, mg/l	220	440	430
Chloride, mg/l	24	40	120
Conductance, umho/cm	1,300	1,600	2,700
Dissolved solids (total), mg/l	1,000	1,900	2,200
Hardness as $CaCO_3$, mg/l	580	1,100	1,100
Magnesium, mg/l	6.5	8.2	18
pH, unit	3.1	-	2.7
Phosphate (total), mg/l	0.11	0.03	0.03
Potassium, mg/l	2.2	3	2.6
Sodium, mg/l	8.1	8.8	11
Sulfate, mg/l	700	1,000	1,200
Turbidity, JTU	<1	<1	2

Table V-77 (Continued)

COMPOSITION OF EFFLUENT FROM ONCE-THROUGH MIST ELIMINATOR WASH UNIT AT WET LIMESTONE SCRUBBER SYSTEM (50)

	Concentration at indicated wash rate		
Water quality parameter	40.7 1/min/m^2	20.35 1/min/m^2	10.18 1/min/m^2
Aluminum, mg/l	<0.2	<0.2	<0.2
Arsenic, mg/l	0.002	0.002	0.01
Barium, mg/l	<0.1	<0.1	<0.1
Beryllium, mg/l	0.01	<0.01	<0.01
Cadmium, mg/l	0.0042	0.0013	0.0031
Chromium, mg/l	<0.05	<0.05	<0.05
Copper, mg/l	0.02	0.02	0.03
Cyanide, mg/l	<0.01	<0.01	<0.01
Iron, mg/l	5.8	0.07	5.5
Lead, mg/l	0.033	0.011	0.016
Manganese, mg/l	0.16	0.14	0.37
Mercury, mg/l	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05
Selenium, mg/l	0.012	0.024	-
Silver, mg/l	<0.01	<0.01	<0.01
Zinc, mg/l	0.07	0.02	0.14

solids to a large pond. After settling, the supernatant from the ponds may be recycled back into the scrubbing process. However, in 1977 only 6 of the total 34 plants (308 data) having operational FGD systems reported closed loop mode of operation. Actual practices at these facilities has not been confirmed at this time. Thus, the supernatant from the majority of plants was directed to the surface waters.

Table V-78 presents range of concentrations of chemicals in the scrubber liquors before settling. Liquor analyses were conducted on 13 samples from seven powerplants burning eastern or western coal and using lime, limestone or double alkali absorbents.

Wastewater Flows. Statistical analysis of wastewater flows from 28 powerplants indicating flue gas scrubber blowdown (308 data) is presented in table V-79. It should be noted that the corresponding question in the questionnaire reads "Flue Gas Scrubber Blowdown." Statistical analysis of wastewater flows categorized as "Scrubber Solids Pond Overflow" is presented in table V-80.

Regenerable Processes

Wellman-Lord Sulfite Scrubbing Process. The Wellman-Lord Sulfite Scrubbing Process is a regenerable flue gas desulfurization process marketed by Davy Powergas. It is based on the ability of a sodium sulfite solution to absorb SO_2 and form a solution of sodium bisulfite. The sodium bisulfite solution can be thermally regenerated to produce a concentrated stream of SO_2 and the original sodium sulfite solution. The concentrated SO_2 stream can be processed to produce elemental sulfur, sulfuric acid, or recycled to the absorber. In the absorption phase of the process, sulfates formed by oxidation of sulfites are removed from the system in a purge of sodium sulfate and sulfite solids.

About 15 percent of the absorber product liquor is sent to purge treatment. The product resulting from the purge treatment is a chrystalline mixture of anhydrous sodium sulfate (70 percent) and sodium sulfite (30 percent) with small amounts of thiosulfates, pyrosulfites and chlorides. The supernatent liquor is recycled (51). There is no planned wastewater or sludge streams associated with this process.

Magnesia Slurry Absorption Process. The Magnesia Slurry Absorption Process is a regenerable flue gas desulfurization process. SO_2 is removed from the flue gases by wet scrubbing with a slurry of magnesium oxide. Magnesium sulfite is the predominant species formed in the absorption reaction below:

$$Mg(OH)_2 + SO_2 \rightleftarrows MgSO_3 + H_2$$

The absorber effuent is centrifuged. The liquor is sent to the slurry tank for combination with makeup water, makeup MgO, and regenerated MgO to form the slurry feed for the scrubber. The magnesium sulfite

Table V-78

RANGE OF CONCENTRATIONS OF CHEMICAL CONSTITUENTS IN FGD SLUDGES FROM LIME/LIMESTONE, AND DOUBLE-ALKALI SYSTEMS (52)

Scrubber Constituent	Liquor, mg/l (except pH)	Solid, mg/kg
Aluminum	0.03-2.0	
Arsenic	0.004-1.8	0.6-52
Beryllium	0.002-0.18	0.05-6
Cadmium	0.004-0.11	0.08-4
Calcium	180-2,600	105,000-268,000
Chromium	0.015-0.5	10-250
Copper	0.002-0.56	8-76
Lead	0.01-0.52	0.23-21
Magnesium	4.0-2,750	
Mercury	0.0004-0.07	0.01-5
Potassium	5.9-100	
Selenium	0.0006-2.7	2-17
Sodium	10.0-29,000	-48,000
Zinc	0.01-0.59	45-430
Chloride	420-33,000	
Fluoride	0.6-58	
Sulfate	600-35,000	35,000-473,000
Sulfite	0.9-3,500	1,600-302,000
Chemical oxygen demand	1-390	
Total dissolved solids	2,800-92,500	
pH	4.3-12.7	

Table V-79

FLUE GAS SCRUBBER BLOWDOWN
(308 Questionnaire)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: Coal*						
Flow:	GPD/plant	34	671,364.7	2,572,498.5	0.00	15,000,000
	GPD/MW	34	811.27	1,877,799	0.00	8,823.53

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*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

Table V-80

FLUE GAS SCRUBBER SOLIDS POND OVERFLOW
(308 Questionnaire)

Variable		Number of Plants	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Fuel: Coal*						
Flow:	GPD/plant	28	210,724.6	580,849.9	0.00	2,310,000
	GPD/MW	28	3,973.31	19,814.926	0.00	195,000

---

*Fuel designations are determined by the fuel which contributes the most Btu for power generation for the year 1975.

cake is dried to remove free and bound water. Magnesium oxide is then regenerated in a calciner by thermal decomposition of the magnesium sulfite according to the equation below:

$$MgSO_3 \rightleftarrows MgO + SO_2$$

The concentrated SO_2 gas stream can be used to promote sulfuric acid or elemental sulfur.

Summary. In general, data sufficient to characterize waste loadings resulting from flue gas cleaning processes are not available. No net discharge data, i.e., influent and effluent data, are currently available for those systems. Additional studies will be needed to provide this data and to confirm the current discharge practices in the industry.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

Section 502 of the Clean Water Act (1) defines a pollutant as follows:

The term "pollutant" means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discharged equipment, rock, sand, cellar dirt and industrial, municipal and agricultural waste discharged into water.

The selection of pollutant parameters for the 1974 Development Document (2) was based on a list of 71 pollutant parameters published by EPA (3) and supplemented by the following pollutant parameters:

- free available chlorine,
- polychlorinated biphenyls, and
- pH.

The pollutant parameters selected and subsequently addressed in the 1974 Development Document (2) were:

- pH,
- total solids,
- total suspended solids,
- total dissolved solids,
- biochemical oxygen demand (BOD),
- chemical oxygen demand (COD),
- chlorine residuals,
- alkalinity,
- acidity,
- total hardness,
- fecal coliform,
- surfactants,
- oil and grease,
- ammonia,

- total phosphorous,
- phenols,
- sulfate,
- sulfite,
- flouride,
- chloride,
- bromide,
- iron,
- copper,
- mercury,
- vanadium,
- chromium,
- zinc,
- magnesium, and
- aluminum.

The selection of pollutant parameters for this document is based on the court approved list of 129 priority pollutants. The assessment of the priority pollutants that may be discharged from steam electric powerplants was based on the analytical results from the sampling program, data from the 308 survey, and information published in the literature. The priority pollutants detected in the sampling program are listed in table VI-1 by waste stream source. Since the sampling program did not include all the plants, pollutants which were not detected at the sampled facilities may be discharged from other facilities. Pollutants at or below the level of quantification may be present at very low concentrations. The number of plants which reported various priority pollutants as known or suspected to be present in their waste streams are presented in table VI-2 by waste stream source. In the 308 survey, powerplants were also requested to provide information regarding proprietary chemicals used during plant operations and their points of application. Table VI-3 provides a listing of those proprietary chemicals reported which contain one or more of the priority pollutants. The specific priority pollutant contained in each chemical was identified from the literature. The addition of any proprietary chemical containing a priority pollutant during operation of a plant would result in the discharge of that pollutant in the plant's wastewater streams, thus, knowledge of the chemical nature of proprietary chemicals and their point of

Table VI-1

PRIORITY POLLUTANTS DETECTED IN THE SAMPLING PROGRAM BY WASTE STREAM SOURCES

Priority Pollutant	Waste Stream Source						
	Once Through Cooling Water	Cooling Tower Blowdown	Combined Ash Sluice Water	Bottom Ash Sluice Water	Fly Ash Sluice Water	Low Volume Waste	Coal Pile Runoff *
Acenaphthene	0	0	0	0	0	0	0
Acrolein	0	0	0	0	0	0	0
Acrylonitrile	0	0	0	0	0	0	0
Benzene	X	X	X	0	0	X	0
Benzidene	0	0	0	0	0	0	0
Carbon Tetrachloride	0	0	0	0	0	0	0
Chlorobenzene	0	0	0	0	0	X	0
1,2,4-Trichlorobenzene	0	0	0	0	0	0	0
Hexachlorobenzene	0	0	0	0	0	0	0
1,2-Dichloroethane	0	0	0	0	0	X	0
1,1,1-Trichloroethane	X	0	0	0	X	X	0
Hexachloroethane	0	0	0	0	0	0	0
1,1-Dichloroethane	0	0	0	0	0	0	0
1,1,2-Trichloroethane	0	0	0	0	0	X	0
1,1,2,2-Tetrachloroethane	0	0	0	0	0	0	0
Chloroethane	0	0	0	0	0	0	0
Bis(Chloromethyl) Ether	0	0	0	0	0	0	0
Bis(2-Chloroethyl) Ether	0	0	0	0	0	0	0
2-Chloroethyl Vinyl Ether (Mixed)	0	0	0	0	0	0	0
2-Chloronaphthalene	X	0	0	0	0	0	0
2,4,6-Trichlorophenol	0	0	0	0	0	0	0
Parachlorometa Cresol	0	0	0	0	0	0	0
Chloroform	X	X	X	0	0	X	0
2-Chlorophenol	0	0	0	0	0	X	0
1,2-Dichlorobenzene	X	0	0	0	0	X	0
1,3-Dichlorobenzene	0	0	0	0	0	0	0

Table VI-1 (Continued)

PRIORITY POLLUTANTS DETECTED IN THE SAMPLING PROGRAM BY WASTE STREAM SOURCES

Priority Pollutant	Waste Stream Source						
	Once Through Cooling Water	Cooling Tower Blowdown	Combined Ash Sluice Water	Bottom Ash Sluice Water	Fly Ash Sluice Water	Low Volume Waste	Coal Pile Runoff *
1,4-Dichlorobenzene	0	0	X	0	0	X	0
3,3-Dichlorobenzidine	0	0	0	0	0	0	0
1,1-Dichloroethylene	X	X	X	0	0	0	0
1,2-Trans-Dichloroethylene	0	0	0	0	0	X	0
2,4-Dichlorophenol	X	X	0	0	0	X	0
1,2-Dichloropropane	0	0	0	0	0	0	0
1,3-Dichloropropene	0	0	0	0	0	0	0
2,4-Dimethylphenol	0	0	0	0	0	0	0
2,4-Dinitrotoluene	0	0	0	0	0	0	0
2,6-Dinitrotoluene	0	0	0	0	0	0	0
1,2-Diphenylhydrazine	0	0	0	0	0	0	0
Ethylbenzene	X	0	X	0	0	X	0
Fluoranthene	0	0	0	0	0	0	0
4-Chlorophenyl Phenyl Ether	0	0	0	0	0	0	0
4-Bromophenyl Phenyl Ether	0	0	0	0	0	0	0
Bis(2-Chloroisopropyl) Ether	0	0	0	0	0	0	0
Bis(2-Chloroethoxy) Methane	0	0	0	0	0	0	0
Methylene Chloride	X	0	X	0	X	X	0
Methyl Chloride	0	0	0	0	0	0	0
Methyl Bromide	0	0	0	0	0	0	0
Bromoform	X	0	0	0	0	X	0
Dichlorobromomethane	0	0	0	0	0	X	0
Trichlorofluoromethane	0	X	X	0	0	0	0
Dichlorodifluoromethane	0	0	0	0	0	0	0
Chlorodibromomethane	X	0	0	0	0	X	0
Hexachlorobutadiene	0	0	0	0	0	0	0

Table VI-1 (Continued)

PRIORITY POLLUTANTS DETECTED IN THE SAMPLING PROGRAM BY WASTE STREAM SOURCES

Priority Pollutant	Waste Stream Source						
	Once Through Cooling Water	Cooling Tower Blowdown	Combined Ash Sluice Water	Bottom Ash Sluice Water	Fly Ash Sluice Water	Low Volume Waste	Coal Pile Runoff *
Hexachlorocyclopentadiene	0	0	0	0	0	0	0
Isophorone	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0
Nitrobenzene	0	0	0	0	0	X	0
2-Nitrophenol	0	0	0	0	0	0	0
4-Nitrophenol	0	0	0	0	0	0	0
2,4-Dinitrophenol	0	0	0	0	0	0	0
4,6-Dinitro-O-Cresol	0	0	0	0	0	0	0
N-Nitrosodimethylamine	0	0	0	0	0	0	0
N-Nitrosodiphenylamine	0	0	0	0	0	0	0
N-Nitrosodi-N-Propylamine	0	0	0	0	0	0	0
Pentachlorophenol	X	0	0	0	0	0	0
Phenol	X	X	X	X	X	X	0
Bis(2-Ethylhexyl) Phthalate	X	X	X	0	X	0	0
Butyl Benzyl Phthalate	X	0	0	0	0	X	0
Di-N-Butyl Phthalate	X	0	0	0	X	0	0
Di-N-Octyl Phthalate	0	0	0	0	0	X	0
Diethyl Phthalate	X	0	0	0	0	0	0
Dimethyl Phthalate	0	0	X	0	0	0	0
Benzo(A)Anthracene	0	0	0	0	0	0	0
Benzo(A)Pyrene	0	0	0	0	0	0	0
Benzo(B)Fluoranthene	0	0	0	0	0	0	0
Benzo(K)Fluoranthene	0	0	0	0	0	0	0
Chrysene	0	0	0	0	0	0	0
Acenaphthylene	0	0	0	0	0	0	0
Anthracene	0	0	0	0	0	0	0
Benzo(G,H,I)Perylene	0	0	0	0	0	0	0

Table VI-1 (Continued)

PRIORITY POLLUTANTS DETECTED IN THE SAMPLING PROGRAM BY WASTE STREAM SOURCES

Priority Pollutant	Waste Stream Source						
	Once Through Cooling Water	Cooling Tower Blowdown	Combined Ash Sluice Water	Bottom Ash Sluice Water	Fly Ash Sluice Water	Low Volume Waste	Coal Pile Runoff *
Fluorene	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0
Dibenzo(A,H)Anthracene	0	0	0	0	0	0	0
Indeno(1,2,3,-C,D)Pyrene	0	0	0	0	0	0	0
Pyrene	0	0	0	0	0	0	0
Tetrachloroethylene	X	X	X	0	0	X	0
Toluene	X	X	X	0	0	X	0
Trichloroethylene	X	0	0	0	0	X	0
Vinyl Chloride	0	0	0	0	0	0	0
Aldrin	0	0	0	0	0	0	0
Dieldrin	0	0	0	0	0	0	0
Chlordane	0	0	0	0	0	0	0
4,4-DDT	0	0	0	0	0	0	0
4,4-DDE	0	0	0	0	0	0	0
4,4-DDD	0	0	X	0	0	X	0
Endosulfan-Alpha	0	0	0	0	0	0	0
Endosulfan-Beta	0	0	0	0	0	0	0
Endosulfan Sulfate	0	0	0	0	0	0	0
Endrin	0	0	0	0	0	0	0
Endrin Aldehyde	0	0	0	0	0	0	0
Heptachlor	0	0	0	0	0	0	0
Heptachlor Epoxide	0	0	0	0	0	0	0
BHC-Alpha	0	0	0	0	0	0	0
BHC-Beta	0	0	0	0	0	0	0
BHC(Lindane)-Gama	0	0	0	0	0	0	0
BHC-Delta	0	0	0	0	0	0	0
PCB-1242 (Arochlor 1242)	0	0	0	0	0	0	0
PCB-1254 (Arochlor 1254)	0	0	0	0	0	0	0

Table VI-1 (Continued)

PRIORITY POLLUTANTS DETECTED IN THE SAMPLING PROGRAM BY WASTE STREAM SOURCES

Priority Pollutant	Waste Stream Source						
	Once Through Cooling Water	Cooling Tower Blowdown	Combined Ash Sluice Water	Bottom Ash Sluice Water	Fly Ash Sluice Water	Low Volume Waste	Coal Pile Runoff *
PCB-1221 (Arochlor 1221)	O	O	O	O	O	O	O
PCB-1232 (Arochlor 1232)	O	O	O	O	O	O	O
PCB-1248 (Arochlor 1248)	O	O	O	O	O	O	O
PCB-1260 (Arochlor 1260)	O	O	O	O	O	O	O
PCB-1016 (Arochlor 1016)	O	O	O	O	O	O	O
Toxaphene	O	O	O	O	O	O	O
Antimony (Total)	X	X	X	X	X	X	O
Arsenic (Total)	X	X	X	X	X	X	O
Asbestos(Total-Fibers/Liter)	O	X	O	O	O	O	O
Beryllium (Total)	O	X	X	X	X	O	X
Cadmium (Total)	X	X	X	X	X	X	X
Chromium (Total)	X	X	X	X	X	X	X
Copper (Total)	X	X	X	X	X	X	X
Cyanide (Total)	O	X	X	O	O	X	O
Lead (Total)	X	X	X	X	X	X	X
Mercury (Total)	X	X	X	X	X	X	O
Nickel (Total)	X	X	X	X	X	X	X
Selenium (Total)	X	X	X	X	X	X	O
Silver (Total)	X	X	X	O	O	X	O
Thallium (Total)	X	X	X	O	X	X	O
Zinc (Total)	X	X	X	X	X	X	X
2,3,7,8-Tetrachlorodibenzo-P-Dioxin	O	O	O	O	O	O	O

Note:
X = Present in greater concentration in the effluent than in the influent at least once.
O = Never present in greater concentration in the effluent than in the influent.
* = Since coal pile runoff has no influent stream (except rainfall), this column reflects whether or not the pollutant was ever detected in the coal pile effluent stream.

Table VI-2

NUMBER OF PLANTS REPORTING VARIOUS PRIORITY POLLUTANTS AS KNOWN OR SUSPECTED TO BE PRESENT IN VARIOUS WASTE STREAMS

(308 questionnaire data)

Priority Pollutant	Number of Plants Reporting by Waste Stream* 1	2	3	4	5	6
Acenaphten	9	0	0	0	0	0
Acrolein	0	0	0	0	0	0
Acrylonitrile	0	1	0	0	0	0
Aldrin-dieldrin	0	0	0	0	0	0
Antimony and Compounds	108	0	3	0	0	15
Arsenic and Compounds	155	13	2	2	11	36
Asbestos	5	0	0	32	9	4
Benzene	0	0	0	2	0	19
Benzidine	0	0	0	0	0	0
Beryllium and Compounds	96	0	0	1	0	15
Cadmium and Compounds	124	1	3	0	8	25
Carbon Tetrachloride	0	0	0	0	0	9
Chlordane	0	0	0	1	0	0
Chlorinated Benzenes	1	0	0	1	0	0
Chlorinated Ethanes	1	0	0	20	0	2
Chlorinated Phenols	0	0	7	1	0	1
Chloroalkyl Ethers	0	0	0	0	0	0
Chloroform	0	0	1	0	0	19
Chromium and Compounds	145	4	40	3	43	45
Copper and Compounds	132	38	8	9	76	69
Cyanides	18	0	0	0	0	12
DDT and Metabolites	0	0	0	0	0	0
Dichlorobenzenes	0	0	0	0	0	0
Dichloroethylenes	0	0	0	0	0	0
Diphenylhydrazine	0	1	0	0	0	0
EDTA	2	7	6	6	0	39

Table VI-2 (Continued)

NUMBER OF PLANTS REPORTING VARIOUS PRIORITY POLLUTANTS AS KNOWN OR SUSPECTED TO BE PRESENT IN VARIOUS WASTE STREAMS

(308 questionnaire data)

Priority Pollutant	Number of Plants Reporting by Waste Stream*					
	1	2	3	4	5	6
Flouranthene	0	0	0	0	0	0
Haloethers	0	0	0	0	0	0
Halomethanes	0	0	0	0	0	0
Heptachlor and Metabolities	0	0	0	0	0	0
Isophorone	1	0	0	0	0	0
Lead and Compounds	132	9	3	12	8	37
Mercury and Compounds	137	11	2	13	0	43
Naphthalene	0	0	0	0	0	14
Nickel and Compounds	137	14	3	3	65	48
Nitrosamines	6	0	0	0	0	0
PCBS	4	0	0	2	0	0
Pentachlorophenol	1	0	9	0	0	1
Phenol	5	6	2	1	2	19
Phthalate Esters	0	0	0	0	0	1
Polynuclear Aromatic Hydrocarbons	1	0	0	0	0	0
Selenium and Compounds	120	0	2	0	1	20
Silver and Compounds	83	3	2	0	0	26
Tetrachloroethylene	0	0	0	1	0	0
Thallium and Compounds	34	0	2	0	0	2
Toluene	0	0	0	0	0	18
Trichloroethylene	0	0	0	5	0	0
Vanadium	94	0	2	0	0	6
Vinyl chloride	0	0	0	0	1	0
Zinc and Compounds	142	7	22	9	59	49

Table VI-2 (Continued)

NUMBER OF PLANTS REPORTING VARIOUS PRIORITY POLLUTANTS AS KNOWN OR SUSPECTED TO BE PRESENT IN VARIOUS WASTE STREAMS

(308 questionnaire data)

Priority Polutant	Number of Plants Reporting by Waste Stream* 1	2	3	4	5	6
2-chlorophenol	0	0	0	0	0	0
2,4 Dichlorophenol	0	0	0	0	0	0
2,4 Dimethylphenol	0	0	0	1	0	7

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*Waste Streams:

1 - ash transport water
2 - water treatment wastes
3 - cooling system wastes
4 - maintenance wastes
5 - construction wastes
6 - other wastes

Table VI-3

PRIORITY POLLUTANT CONTAINING PROPRIETARY CHEMICALS USED BY POWER PLANTS

(308 questionnaire data)

Proprietary Chemical (point of application*)	Specific Priority Pollutant Contained in Product (4,5)
NALCO CHEMICALS	
25L (CT)*	COPPER
37 (BW)	CHROMIUM
38 (CW)	CHROMIUM
75 (BW)	PHENOL
201 (CT)	CHLORINATED PHENOLS
344 (CT)	ACRYLONITRILE
375 (CW)	CHROMIUM
425L (BW)	COPPER
CALGON CHEMICALS	
CL-70 (CT)	ZINC CHLORIDE
CL-35 (BW)	SODIUM DICROMATE
CL-68 (CW)	SODIUM DICHROMATE, ZINC CHLORIDE
DEARBORN CHEMICALS	
712 (CW)	CHLORINATED PHENOLS
BETZ CHEMICALS	
BETZ 40P (CW)	CHROMATE AND ZINC SALTS
BETZ 403 (CW)	CHROMATE AND ZINC SALTS
DIANODIC 191 (CW)	CHROMATE AND ZINC SALTS
DOW CHEMICALS	
DOWICIDE GB (ALGACIDE)	CHLORINATED PHENOLS
HERCULES CHEMICALS	
CR 403 (CT)	ZINC DICHROMATE, CHROMIC ACID
DUPONT	
KARMEX (CW)	CHLORINATED PHENOLS

Table VI-3 (Continued)

PRIORITY POLLUTANT CONTAINING PROPRIETARY CHEMICALS USED BY POWER PLANTS

(308 questionnaire data)

Proprietary Chemical (point of application*)	Specific Priority Pollutant Contained in Product (4,5)
DREW CHEMICALS	
BIOSPERSE 201 (CW)	CHLORINATED ETHANES
ASHLAND CHEMICALS	
1,1,1-TRICHLOROETHANE (FA)	CHLORINATED ETHANES
BURRIS CHEMICALS	
SODIUM DICHROMATE (CT)	SODIUM DICHROMATE

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*Point of Application:

BW - BOILER WATER
CT - COOLING TOWER
CW - COOLING WATER
FA - FUEL ADDITIVE

application was an additional way of identifying priority pollutants in powerplant wastewater discharges.

At the time of the preparation of this document, water quality criteria for the 65 families of toxic pollutants were not available. Proposed criteria, however, were available for 27 of the pollutant families. The criteria used are presented in table VI-4. Water quality criteria are not an absolute constraint on effluent guidelines development; they are one of many factors considered.

Table VI-4

WATER QUALITY AND HUMAN HEALTH CRITERIA USED IN ASSESSMENT OF ENVIRONMENTAL SIGNIFICANCE OF POWER PLANT EFFLUENTS

(ppb)

Pollutant	Water Quality Criteria				Human Health Criteria
	Freshwater		Marine		
	FT	FX	MT	MX	
Benzene	3100	7000	920	2100	15
1,2-dichloroethane					
2-chloronaphthalene					
2,4,6-trichlorophenol	52	150			
chloroform	500	1200	620	1400	2.1
1,2-dichlorobenzene	44	99	15	34	270 Total
1,3-dichlorobenzene	310	700	22	49	
1,4-dichlorobenzene	190	440	15	34	
1,1-dichloroethylene	530	1200	1700	3900	0.48
1,2-trans-dichloroethylene	620	1400			
2,4-dichlorophenol	0.4	110			0.5
methylene chloride	4000	9000	1900	4400	
bromoform	840	1900	180	420	
chlorodibromomethane					
2,4-dinitrophenol					
pentachlorophenol	6.2	14	3.7	8.5	140
phenol	600	3400			
trichloroethylene	1500	3400			21
1,1,2,2-tetrachloroethane			38	87	
ethylbenzene					
isophorone			97	220	
bromodichloromethane					
tetrachloroethylene	310	700	79	180	2.2

Table VI-4 (Continued)

WATER QUALITY AND HUMAN HEALTH CRITERIA USED IN ASSESSMENT OF ENVIRONMENTAL SIGNIFICANCE OF POWER PLANT EFFLUENTS

(ppb)

Pollutant	Water Quality Criteria				Human Health Criteria
	Freshwater		Marine		
	FT	FX	MT	MX	
antimony					
arsenic	57	130	29	67	0.02
asbestos					
chromium	5	280	25	260	
copper	0.3-15	3.5-60	0.88	2	
cyanides	1.4	42			
mercury	0.003	3.2	0.089	1.6	
nickel	2-100	45-600			
selenium	9.7	22	4.4	10	10
silver	0.009	1.9	0.26	0.58	20
thallium					4
zinc	7-10	35-400	48	110	
beryllium	FT=e exp (1.24 ln(hardness)-6.65) FX=e exp (1.24 ln(hardness)-1.46)				0.087
cadmium	FT=e exp (0.867 ln(hardness)-4.38) FX=e exp (1.30 ln(hardness)-3.92) MT=1 MX=16				10
lead	FT=e exp (1.51 ln(hardness)-3.37) FX=e exp (1.51 ln(hardness)-1.39)				50

SECTION VII

TREATMENT AND CONTROL TECHNOLOGY

INTRODUCTION

This section addresses treatment and control technologies judged to be effective in reducing or eliminating pollutants from steam electric power wastewaters. Wastewaters from steam electric powerplants vary in both quality and quantity from one plant to another. Control of pollutants, however, can be achieved in a uniform manner. The treatment and control technologies described in this section are those technologies which are available or currently in use in the steam electric power industry to decrease the discharge of toxic pollutants to navigable waters. The discussion of technologies is organized by major waste streams and waste stream categories: cooling water, ash handling, low volume wastes, metal cleaning wastes, and coal pile runoff.

COOLING WATER

The variety of pollutants which may be present in cooling water discharges from steam electric powerplants were identified in Section V. In Section VI the major pollutants of concern were identified as total residual chlorine (TRC) and certain priority pollutants.

The technologies which have been evaluated for control of TRC include:

- chlorine minimization,
- dechlorination,
- alternative oxidizing chemicals,
- mechanical cleaning,
- biocidal soak,
- antifouling coatings,
- heat treatment,
- gamma irradiation and ultraviolet radiation,
- ultrasonic vibration,
- modified water velocity,
- osmotic shock, and
- anoxic water.

EPA evaluated each of these technologies. Many were eliminated from further consideration for various reasons including:

- The technology was not believed to be applicable to a large population of plants;
- The technology was judged to be too complex to be reliably operated and maintained at a steam electric plant; or
- No data was available to establish the effectiveness of the technology in use at steam electric power plants or in similar biofouling control applications.

The technologies chosen for full consideration were:

- chlorine minimization,
- dechlorination,
- alternative oxidizing chemicals, and
- mechanical cleaning.

Several of the 129 priority pollutants have been observed in cooling tower blowdown. The sources of these priority pollutants are chemical additives used for corrosion, scaling, and biofouling control and asbestos fill material from the cooling towers. The only feasible technology for priority pollutant control is substitution of products not containing priority pollutants for products that do contain these pollutants. Chemical mixtures not containing priority pollutants can be substituted for scaling and corrosion control chemicals and non-oxidizing biocides. Replacement of asbestos cement cooling tower fill with another type of fill eliminates the release of asbestos fibers in cooling tower blowdown.

A process description, an effectiveness evaluation, and a discussion of the limitations for each of these technologies are presented in this subsection.

Total Residual Chlorine Control with Chlorine Minimization

Chlorine minimization is defined as any modification of a current cooling water chlorination program that reduces to the minimum possible level the loading of total residual chlorine (TRC) placed on a receiving water by the once-throgh cooling water system of a steam electric powerplant. Loading is the product of three factors: cooling water flowrate, TRC concentration in the cooling water discharge, and the length of time TRC is present in the discharge. Reduction of cooling water flow rate is not practical in a once-through system; therefore, chlorine minimization can be accomplished by reducing any of the following:

- Dose of chlorine added; where dose is defined as the total weight of chlorine added per unit volume of cooling water, i.e., 1 mg/l, 2 mg/l, etc.;

- Duration of chlorination period; where duration is defined as the length of time between the start and end of a single period of chlorine addition; or
- Frequency of chlorination; where frequency is defined as the number of times per day that chlorination periods occur.

In addition, combinations of dose, duration and frequency may be reduced simultaneously to bring about a reduction in net loading of TRC to the environment.

Some plants add chlorine continuously in order to control biofouling from barnacles or fresh water clams. Often a low dose of chlorine is applied continuously for control of the hard shelled organisms--which can close their shell and endure intermittent chlorination periods--and a higher dose is applied intermittently at some duration and frequency for the control of biological slimes. Thus, plants which chlorinate continuously may be able to apply chlorine minimization by reducing their chlorine dose-for continuous chlorination--and reducing their dose, duration or frequency for intermittent chlorination.

Chlorine minimization was considered only for plants with oncethrough cooling water systems. For plants with recirculating systems, the cooling towers as well as the condensers are susceptible to biofouling. The need to control biofouling in the cooling towers not only greatly complicates chlorine minimization but also increases the risk of serious biofouling during a chlorine minimization program.

Description of a Chlorine Minimization Program

A chlorine minimization program as described here has three components: upgrading the existing chlorination facility, conducting a minimization study, and implementing the recommendations of the study.

Upgrading Existing Chlorination Facility. An adequate chlorination facility includes an equipment module, an instrumentation module, and a structural module.

The equipment module contains the chlorine supply system. Two types of chlorine supply systems are used: chlorine gas systems and sodium hypochlorite generation systems. Sodium hypochlorite systems are considerably more expensive than gas feed systems and have seen limited application, primarily at plants which needed to avoid the necessity for regular deliveries of chlorine gas cylinders, or at plants where safety considerations suggested the use of a system not involving chlorine gas. Since the use of sodium hypochlorite generators is limited, the analysis does not consider these units further; nevertheless, the concepts of chlorine minimization developed for gas feed chlorination systems can be similarly applied to hypochlorite generation systems.

In gas feed chlorination systems, chlorine is manufactured offsite, compressed in steel containers, and shipped to the plant site as a liquid. Containers with a wide range of capacities are used. Cylinder capacity commonly ranges from 150 pounds to 1 ton of chlorine. Selection of container size is primarily a function of average daily chlorine consumption. Selection of the number of containers is primarily a function of facility design capacity and method of withdrawal (1). Generally, systems with a chlorine withdrawal requirement of more than 17 pounds per hour per 1 ton container use liquid withdrawal systems. Most steam electric powerplants fall into this category. Some small plants may use gas withdrawal systems.

Transmission of the chlorine from the containers to the metering system differs for gas withdrawal and liquid withdrawal. For gas withdrawal, the gas passes through a filter and, in some cases, a pressure-reducing valve. The filter removes impurities in the chlorine gas which might inhibit the functioning of some equipment in the metering system. When there is a danger of reliquefaction of the gas between the containers and the metering system, a pressure-reducing valve is used to lower the pressure of the gas which, in turn, lowers the temperature at which liquefaction would occur.

For liquid withdrawal, the liquid passes through an evaporator which converts the liquid to chlorine gas and then the gas passes through a filter and, in some cases, a pressure-reducing valve just as in gas withdrawal. A flow diagram of a liquid withdrawal system is shown in figure VII-1. The evaporator consists of an inner liquid chlorine chamber surrounded by an electrically heated water bath. Expansion chambers are usually provided on the liquid chlorine line between the containers and the evaporator to prevent rupture of the pipe in the event of capture of liquid in the line and subsequent temperature rise. Whether gas or liquid withdrawal is used, chlorine gas enters the metering system since liquid is converted to gas during transmission from the containers (1).

The metering system--usually referred to as the chlorinator--is shown in figure VII-2. The chlorinator is activated by a vacuum created by the injector system. The vacuum opens the diaphragm check valve, the vacuum regulating valve, and the pressure-vacuum relief valve which allows air to enter the system. The vacuum also opens the gas pressure regulating valve so that when the chlorine supply system is opened, chlorine gas will flow through to the injector. When the gas flow satisfies the vacuum, the pressure-vacuum relief valve closes, stopping the flow of air into the system. The rate of chlorine gas flow is controlled by the feed rate valve, and the vacuum-regulating valve. By adjusting the feed rate valve, the flow of chlorine gas can be limited to values less than the capacity of the rotameter.

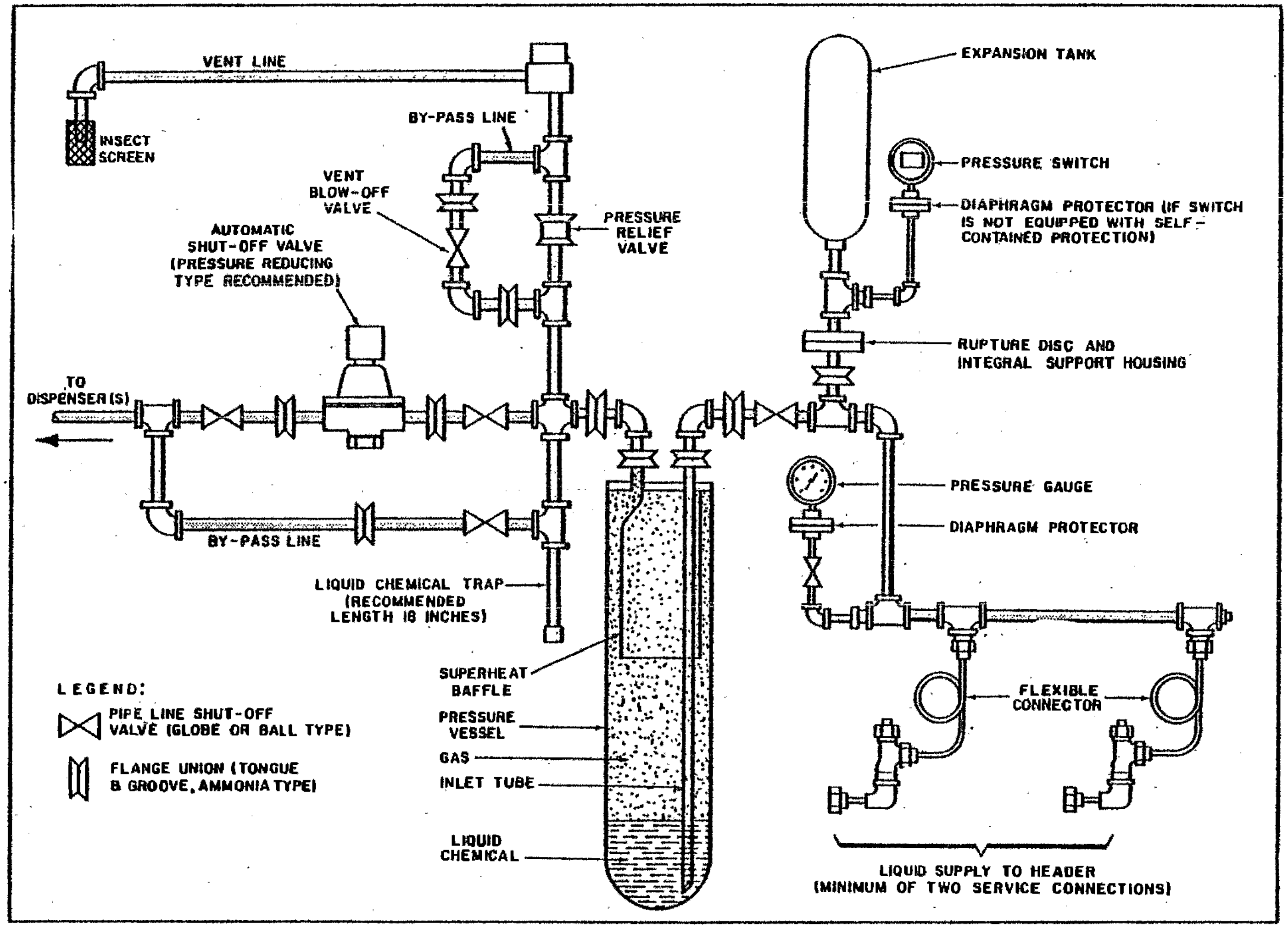

VENT LINE
INSECT SCREEN
BY-PASS LINE
VENT BLOW-OFF VALVE
PRESSURE RELIEF VALVE
AUTOMATIC SHUT-OFF VALVE (PRESSURE REDUCING TYPE RECOMMENDED)
TO DISPENSER(S)
BY-PASS LINE
LIQUID CHEMICAL TRAP (RECOMMENDED LENGTH 18 INCHES)
LEGEND:
PIPE LINE SHUT-OFF VALVE (GLOBE OR BALL TYPE)
FLANGE UNION (TONGUE & GROOVE, AMMONIA TYPE)
SUPERHEAT BAFFLE
PRESSURE VESSEL
GAS
INLET TUBE
LIQUID CHEMICAL
EXPANSION TANK
PRESSURE SWITCH
DIAPHRAGM PROTECTOR (IF SWITCH IS NOT EQUIPPED WITH SELF-CONTAINED PROTECTION)
RUPTURE DISC AND INTEGRAL SUPPORT HOUSING
PRESSURE GAUGE
DIAPHRAGM PROTECTOR
FLEXIBLE CONNECTOR
LIQUID SUPPLY TO HEADER (MINIMUM OF TWO SERVICE CONNECTIONS)

Figure VII-1

LIQUID SUPPLY CHLORINATION SYSTEM

Reprinted from Instruction Bulletin 70-9001 by Fischer and Porter Co., April, 1977.

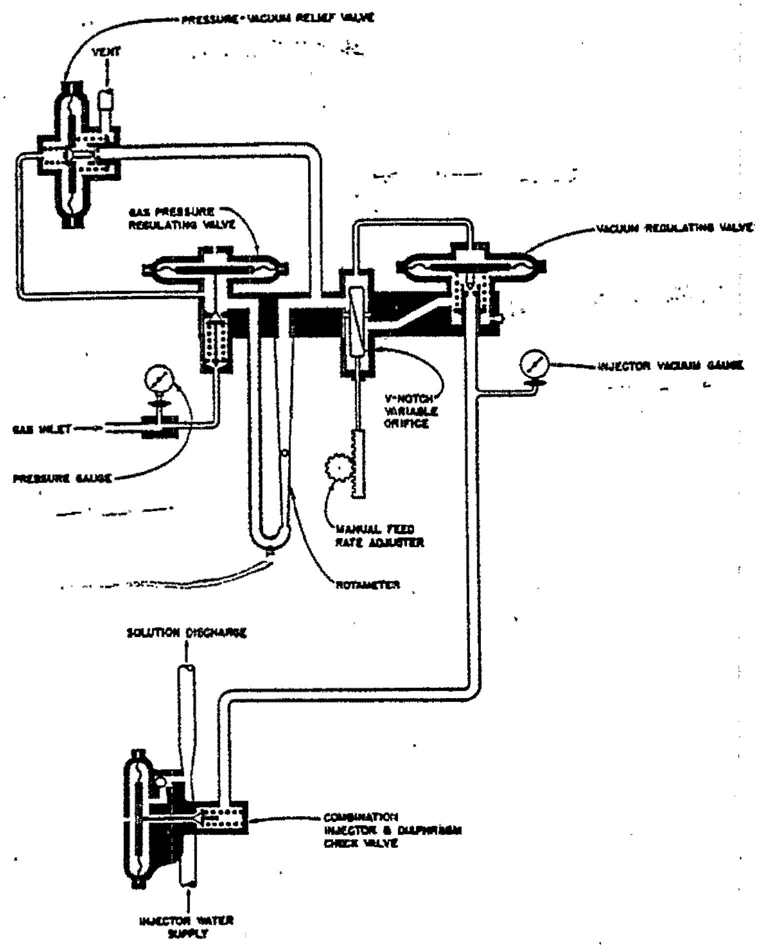

PRESSURE-VACUUM RELIEF VALVE
VENT
GAS PRESSURE REGULATING VALVE
VACUUM REGULATING VALVE
INJECTOR VACUUM GAUGE
V-NOTCH VARIABLE ORIFICE
GAS INLET
PRESSURE GAUGE
MANUAL FEED RATE ADJUSTER
ROTAMETER
SOLUTION DISCHARGE
COMBINATION INJECTOR & DIAPHRAGM CHECK VALVE
INJECTOR WATER SUPPLY

Figure VII-2

SCHEMATIC DIAGRAM OF A TYPICAL CHLORINATOR

Reprinted from Handbook of Chlorination by G. C. White by permission of Van Nostrand Reinhold Company. Year of first publication: 1972.

The last component of the equipment module is *the injector system* which consists of a booster pump, an injector, and a diffuser. The injector is the key component of the system. It is essentially a constriction in the pipe carrying the water in which the chlorine gas is dissolved. The constriction causes an increase in water velocity, thus creating the vacuum that activates the metering system. The chlorine gas from the metering system enters the injector system at this point and is dissolved in the water in the turbulent discharge of the injector (1).

In order for the injector to operate properly, an adequate flow of water at the proper pressure must be supplied by the booster pump. The flow must be ample enough to limit the concentration of chlorine in solution to 3,500 ppm and to create a vacuum of about 25 inches of mercury. If the concentration of chlorine in solution exceeds 3,500 ppm, chlorine gas will come out of solution causing fuming at the point of application and gas binding in the chlorine solution line. If the vacuum falls below 25 inches of mercury, the metering system will not operate properly. The flow of water required to avoid these problems can be determined from manufacturer's injector efficiency curves. The pressure must be high enough to overcome the back pressure on the injector and the pressure loss through the injector. The back pressure on the injector is the sum of the static pressure at the point of injection and friction losses in the piping between the injector and the point of injection. The pressure loss through the injector can also be determined from manufacturer's injector efficiency curves. Given the required discharge volume and pressure, the proper booster pump can be selected (1).

The hypochlorus acid solution from the injector is dispersed in the cooling water with a diffuser. Two basic types of diffusers are available. For pipelines flowing full, the diffusers are essentially pipes mounted on the cooling water conduit perpendicular to the flow of cooling water and discharging at the center of the conduit. For open channel flow, the diffusers are perforated pipes mounted in the open channel. In steam electric powerplant applications, the open channel condition exists when the hypochlorous acid solution is added to the cooling water before it enters the circulating water pumps, and the full pipeline condition exists when the hypochlorous acid solution is added to the cooling water before it enters the condensers (1).

The instrumentation module consists of timers, a chlorine residual analyzer/recorder, a scale, and a chlorine leak detector. Timers are applicable to intermittent chlorination, not to continuous chlorination. The timers automatically start and stop the booster pump which in turn activates and deactivates the equipment module. The timers are set so that chlorination occurs with the frequency and duration desired. The chlorine residual analyzer/recorder continuously analyzes for total residual chlorine in the cooling water discharge and overrides the timers to stop the booster pump if the total residual chlorine concentration exceeds a predetermined level. The scale is used to weigh the chlorine containers in service in order to track consumption and to determine when containers need to be replaced. The chlorine leak detector monitors the air in the chlorination building for chlorine gas and sounds an alarm if any of the gas is detected (2).

The structural module consists of a building for the equipment and instrumentation modules. The building must be properly ventilated and heated. When 1 ton chlorine containers are being used, a hoist must be provided with the building (1).

Chlorine Minimization Study. The chlorine minimization study consists of three phases. The first phase establishes the following relationships:

- condenser performance and dose of chlorine added to the cooling water,
- condenser performance and duration of chlorination period, and
- condenser performance and frequency of chlorination.

Condenser fouling is commonly measured in terms of turbine back pressure. The second phase consists of screening trials in which the chlorine residual in the cooling water discharge, the duration of the chlorination events, and the frequency of the chlorination events are each reduced below the baseline level until condenser performance drops below the baseline levels. The screening trials define the minimum chlorine dose, duration and frequency levels which can maintain adequate condenser performance. The third phase is a long-term trial of the chlorine minimization program defined in the second phase. The minimum chlorine dose, duration, and frequency are maintained and condenser performance is monitored. If performance is satisfactory over the long term, the chlorine minimization program is instituted permanently (3,4,5).

Almost all of the data required to conduct the study are collected as part of the normal operation and maintenance procedure in plants with an adequate chlorination facility. The normal operation and maintenance procedure for the chlorination facility includes daily logging of the chlorine scale readings, daily logging of timer settings, changing the chart on the chlorine residual analyzer, and weekly checks of the analyzer using an amperometric titrator. The normal operation and maintenance procedure for the plant is assumed to include daily logging of cooling water flow, changing charts on the turbine back pressure recorder, and sampling and analysis of intake water quality. The only data not collected as part of normal operation and maintenance procedure is a qualitative evaluation of the degree of biofouling in the condensers. A visual inspection of the condenser can be conducted at the conclusion of each screening trial. The inspection, however, requires taking the condenser out of service, which is very costly in terms of lost power output from the plant.

The performance data are analyzed. The analyses include correlating intake water quality and chlorine demand, relating chlorine demand to chlorine dosage, and plotting turbine back pressure, TRC level, duration of chlorination, and frequency of chlorination versus time. The analyses are performed at different intervals for each phase of the study. The frequency of analysis is greatest in the second phase since the results of the analyses are used to operate the chlorination facility.

The study procedure is applicable not only to a plant practicing intermittent chlorination but also to a plant practicing continuous chlorination with the addition of a parallel set of steps to determine the minimum dosage required to control biofouling in the intake structure and the pipeline.

Implementing Study Recommendations. The final step in the chlorine minimization program is implementing the recommendations of the study. Assuming that reductions in duration of chlorination, dose, or frequency of chlorination are recommended, the minimum values become the permanent basis of chlorination facility operation.

Application to a Model Plant

The model plant is assumed to have the following characteristics:

- two baseload generating units of equal capacity;
- once-through cooling water system for both units;
- separate circulating water pumps for each unit;
- same cooling water flow rate through the condensers of each unit;
- chlorine addition on the intake side of the circulating water pumps;
- chlorination of the units in series, not in parallel;
- intermittent chlorination only;
- chlorination required during all seasons of the year;
- chlorination requirements varying with season of the year;
- existing chlorination equipment, structural, and instrumentation modules; and
- in operation for several years so that baseline levels of chlorination are well defined.

As the first step in the minimization program, the existing chlorination facility is evaluated. Assume that the existing equipment, structural, and instrumentation modules are adequate. The first phase of the study consists of establishing the following baseline relationships:

- water quality and chlorine demand of the cooling water,
- chlorine demand of the cooling water and dosage of chlorine required to obtain a given chlorine residual,
- condenser performance and chlorine residual in the cooling water,
- condenser performance and duration of chlorination events, and
- condensor performance and frequency of chlorination events.

Condenser performance is measured by condenser back pressure or, in some cases, turbine back pressure. In order to establish the baseline relationships, the following measurements are taken with the specified frequency:

- relevant intake water quality parameters once per week;
- chlorine demand of the intake water once per week;
- flow rate of cooling water to each unit once per week;
- weight of chlorine container(s) in use once per week;
- turbine back pressure once per shift;
- TRC at the plant discharge continuously, change chart on recorder once per day;
- settings of timers that start and stop chlorination once per day, and
- check of TRC analyzer once per week with an amperometric titrator and adjustment of the analyzer, if necessary.

Each season, or once every 3 months, the data are analyzed as follows:

- correlations between intake water quality parameters and chlorine demand of the intake water are checked;
- the flow rate of cooling water pumped to each unit and the consumption of chlorine are used to calculate the chlorine dosage;
- a graph of chlorine demand versus chlorine dosage is made;

and

- graphs of turbine back pressure, TRC level, duration of chlorination, and frequency of chlorination versus time are made. The unit of time used should be 8 hours or one shift.

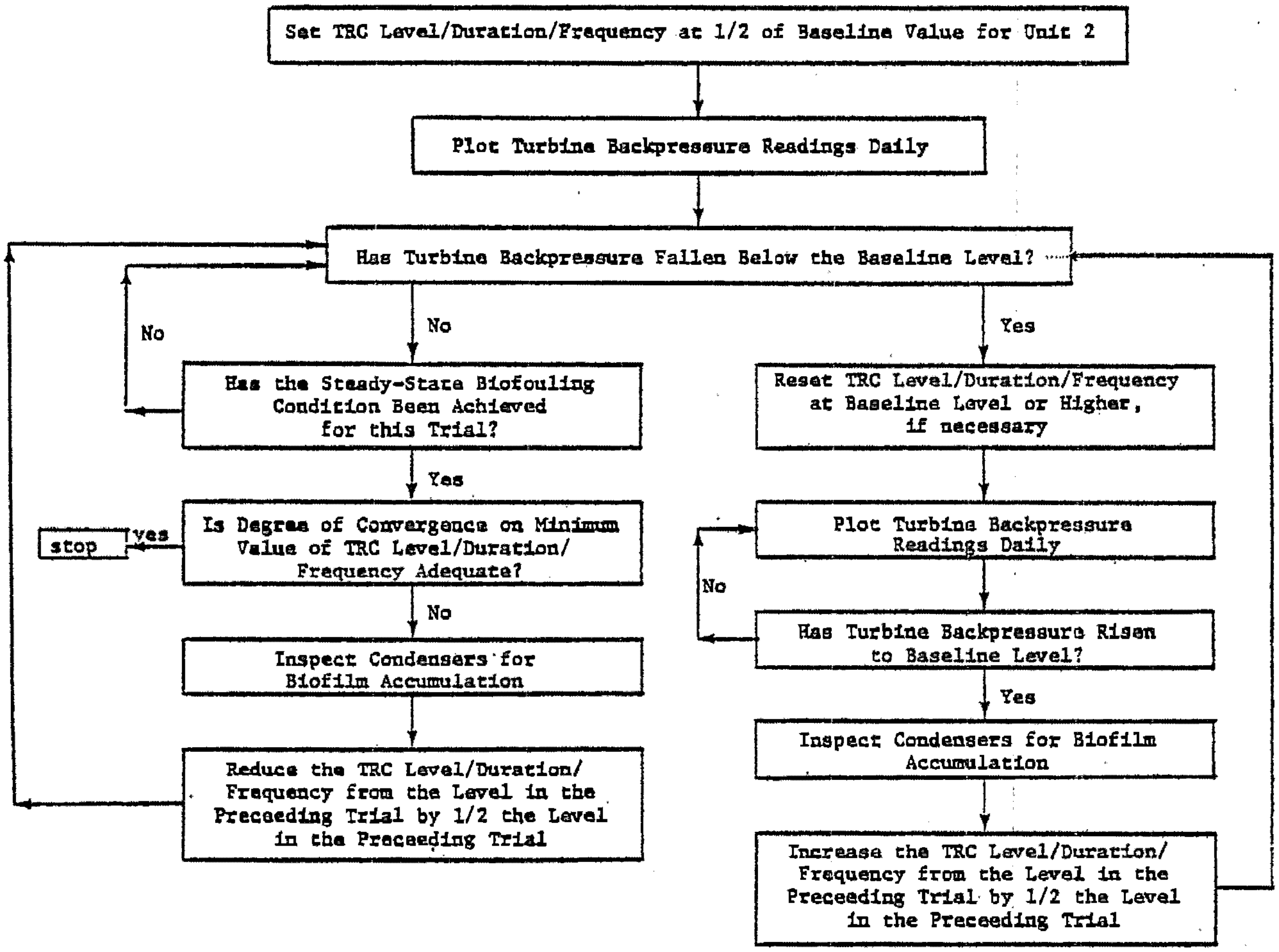
Throughout the 18 month long study, screening trials are conducted. Throughout all of the screening trials, the TRC level and frequency and duration of chlorination for Unit 1 are maintained at the baseline levels for the appropriate season of the year in order to detect any shifts in the baselines. A visual inspection may be held at the end of one or more of the screening trials.

The information from the visual inspections of the condensers is used to qualitatively confirm the turbine back pressure readings. A set of screening trials is conducted for each chlorination parameter: dose, duration, and frequency of chlorination. The objective of each set of trials is to converge on the minimum value for the parameter under consideration. The other two parameters are held constant. The procedure for conducting a set of screening trials is shown in figure VII-3. The set of screening trials for TRC level are conducted first using the baseline levels for duration and frequency of chlorination for the appropriate seasons of the year. After the minimum TRC level has been determined, the set of screening trials for duration of chlorination are conducted using the seasonally adjusted minimum TRC level and the baseline level of chlorination frequency for the appropriate season of the year. At the completion of this set of trials, the set of screening trials for frequency of chlorination is conducted using the seasonally adjusted minimum TRC level and the seasonally adjusted minimum duration of chlorination. When all three sets of screening trials have been completed, the minimum values of TRC level, duration of chlorination, and frequency of chlorination are known.

The final step in the chlorine minimization program is implementing the recommendations of the study. Assuming that the study recommended reductions in TRC level, duration of chlorination, and frequency of chlorination, the four sets of seasonal minimum values become the permanent basis of chlorination facility operation. The same measurements which were made in the minimization study become part of the data base on plant operation that is generated as standard operating procedure. The analysis of the data is also assigned to the plant operating staff with the assistance of appropriately designed calculation sheets and graph paper. In essence, the chlorine minimization program loses its identity in this final step as it is completely integrated into the normal operation of the plant. A detailed discussion of the necessary steps in conducting a chlorine minimization program is provided in Appendix B.

Figure VII-3

PROCEDURE FOR CONDUCTING A SET OF SCREENING TRIALS TO CONVERGE ON THE MINIMUM VALUE FOR TRC LEVEL, DURATION OF CHLORINATION, AND CHLORINATION FREQUENCY


Set TRC Level/Duration/Frequency at 1/2 of Baseline Value for Unit 2
Plot Turbine Backpressure Readings Daily
Has Turbine Backpressure Fallen Below the Baseline Level?
No
No
Yes
Has the Steady-State Biofouling Condition Been Achieved for this Trial?
Yes
Is Degree of Convergence on Minimum Value of TRC Level/Duration/Frequency Adequate?
yes
stop
No
Inspect Condensers for Biofilm Accumulation
Reduce the TRC Level/Duration/Frequency from the Level in the Preceeding Trial by 1/2 the Level in the Preceeding Trial
Reset TRC Level/Duration/Frequency at Baseline Level or Higher, if necessary
Plot Turbine Backpressure Readings Daily
No
Has Turbine Backpressure Risen to Baseline Level?
Yes
Inspect Condensers for Biofilm Accumulation
Increase the TRC Level/Duration/Frequency from the Level in the Preceeding Trial by 1/2 the Level in the Preceeding Trial

Effectiveness

The objective of a chlorine minimization program is to reduce the loading of total residual chlorine (TRC) into the receiving water as much as possible without impairing condenser performance. The degree to which this objective is achieved--the effectiveness of chlorine minimization--is measured in terms of the TRC level at the point of cooling water discharge and the length of time that chlorine is added to the cooling water per day. Data on these two measures of effectiveness were compiled from various studies of efforts to reduce the quantity of chlorine discharged at operating powerplants. Very little data from efforts to reduce the length of time that chlorine is added to the cooling water were found. It should be noted, however, that the current limitation was not exceeded in any of the studies. An adequate amount of data from efforts to reduce TRC level was found, therefore, an assessment of the effectiveness of chlorine minimization was conducted by analyzing data on TRC levels only.

The TRC data which were extracted from the chlorine minimization and reduction studies are presented in table VII-1. Twenty-two plants, all with once-through cooling water systems, are represented. Seven out of the 11 nuclear plants shown in table VII-1 were able to maintain adequate biofouling control at plant discharge levels below 0.1 mg/l. The NRC studies were among the most carefully conducted; it is believed they represent levels that should be achievable for many fossil fuel plants.

A statistical evaluation of the effectiveness of chlorine minimization at three Michigan power plants is presented in Appendix C. On the average, the three plants were able to reduce their effluent TRC concentrations by 40 percent through the use of a chlorine minimization program.

Potential Operating Problems

A chlorine minimization program requires close monitoring by the operating staff of a steam electric powerplant to insure that several problems do not arise. First, the likelihood of severe condenser biofouling is increased. If this biofouling does occur, the condenser has to be treated with very high dosages of chlorine or be taken out of service for manual cleaning. Severe biofouling is more likely because there is no measure of condenser performance that unambiguously reflects the formation of biofilm on condenser tubes. The measure of condenser performance selected for the recommended minimization program, turbine back pressure, is affected by factors other than biofilm formation, principally, debris blocking the condenser tubes. The other measures of condenser performance, heat transfer efficiency and pressure drop across the condenser, are similarly afflicted and require more data to calculate (5). Second, the units on which screening trials are being conducted for the minimization study have to be shutdown for visual inspection of the condenser tubes at the end of each screening trial. The shutdowns reduce the power output of the plant and require more operator time

Table VII-1

TOTAL RESIDUAL CHLORINE DATA REPORTED IN CHLORINE MINIMIZATION STUDIES

Plant Number	Recommended* TRC Level (mg/l)	Sampling Point	Comments	Reference
4223	0.5	Condenser outlet	Condenser performance declined at 0.2, but not 0.5	6
4229	1.0	Condenser outlet	Condenser performance declined at 0.5, but not 1.0	6
4225	1.5	Condenser outlet	Condenser performance declined at 1.0, but not 1.5.	6
5513	1.0	Condenser outlet		3
4704	0.2	Condenser outlet		7
1719	0.4	Plant discharge	Level frequently exceeded.	8
1713	0.2	Plant discharge	Level exceeded 73% of the time.	8
1825	0.2	Plant discharge	Level cannot be consistently met.	9
4206	0.2	Plant discharge		10
0512	0.1	Plant discharge		11
2630	0.1	Plant discharge	Six violations in three years	11
5519	0.1	Plant discharge		11
5514	0.1	Plant discharge		11
1221	1.8	Plant discharge		11
0905	0.1	Plant discharge		11
3608	0.2	Plant discharge		11
0904	0.1	Plant discharge		11
2506	0.5	Plant discharge	One violation in three years	11
1248	0.1	Plant discharge		11
0629	1.0	Plant discharge	Two violations in three years	11
2705	0.2	Plant discharge		12
2708	0.2	Plant discharge		13

*Recommended level represents the maximum TRC concentration expected to be used during worst case plant conditions. Lower TRC levels often produce adequate biofouling control.

for the shutdown and startup procedures. *Unfortunately, no other method of evaluating turbine back pressure readings is available (5).* Some of the inspections may be required at times when the units are shutdown for other reasons, thus minimizing the impact of the inspections. Third, the total residual chlorine measurements may be in error when the cooling water is drawn from an estuary. Errors to the high side could cause premature shutdown of the chlorination facility and thus increase the potential for severe biofouling of the condensers. Errors to the low side could create toxic conditions in the receiving stream as a result of the chlorination facility not shutting down when a predetermined level of TRC is exceeded.

The potential operating problems which have been mentioned should be known to the operators of a plant before a chlorine minimization program is begun so that the operators can deal with the problems as effectively as possible.

Total Residual Chlorine Control with Dechlorination

Dechlorination is the process of adding a chemical-reducing agent to the cooling water which reduces chlorine to chloride, a nontoxic chemical. There are numerous reducing agents available for this purpose. Only a few have shown themselves to be practical for use in the water and wastewater treatment industry (15):

1. Sulfur Dioxide (SO_2)

2. Salts Containing Oxidizable Sulfur
    a. Sodium Sulfite (Na_2SO_3)
    b. Sodium Metabisulfite ($Na_2S_2O_5$)
    c. Sodium Thiosulfate ($Na_2S_2O_3$)

3. Natural Chlorine Demand

4. Ferrous Sulfate ($FeSO_4$)

5. Ammonia (NH_3)

6. Activated Carbon (C)

7. Hydrogen Peroxide (H_2O_2)

The use of ferrous sulfate, ammonia, activated carbon, or hydrogen peroxide for dechlorination at powerplants has been evaluated and found to be technically and/or economically infeasible (15). Any dechlorination systems in which these chemicals are used were, therefore, not given further consideration. Dechlorination systems using sulfur dioxide, salts of oxidizable sulfur and natural chlorine demand are discussed in detail in the following subsections.

Sulfur Dioxide System

Chemical Reactions. The most common form of dechlorination as practiced in the water and wastewater treatment industry is injection of sulfur dioxide (SO_2) (1). When injected into water, sulfur dioxide reacts instantaneously to form sulfurous acid (H_2SO_3):

$$SO_2 + H_2O \rightleftarrows H_2SO_3 \qquad (13)$$

The sulfurous acid, in turn, reacts instantaneously with hypochlorous acid (HOCl):

$$H_2SO_3 + HOCl \rightleftarrows H_2SO_4 + HCl \qquad (14)$$

Monochloramine also reacts with sulfurous acid:

$$H_2SO_3 + NH_2Cl + H_2O \rightleftarrows NH_4HSO_4 + HCl \quad (15)$$

Both dichloramine and nitrogen trichloride are also reduced by sulfur dioxide in similar reactions. The reaction of sulfur dioxide with hypochlorous acid (HOCl) is virtually instantaneous. Reactions with monochloramine and the other combined forms proceed slightly more slowly (16).

Equipment. The equipment required for dechlorination by sulfur dioxide injection is shown in figure VII-4. As indicated in the figure, a complete system includes the following pieces of equipment:

- SO_2 storage containers,
- expansion chamber-rupture disk,
- SO_2 evaporator,
- SO_2 gas regulator,
- sulfonator,
- ejector;
- ejector pump,
- building for system housing, and
- required timers and control system.

The equipment required for dechlorination by sulfur dioxide injection is identical to the equipment required for chlorination, and the description of chlorination equipment is also applicable to the sulfur dioxide dechlorination system. Equipment manufacturers sell the same equipment for both chlorination and sulfur dioxide dechlorination applications. The capacities of the equipment are different in each application due to differences in the properties of the two gases. Also shown in figure VII-4 is a typical diffuser assembly installation in a discharge conduit. The number of diffuser installations and the

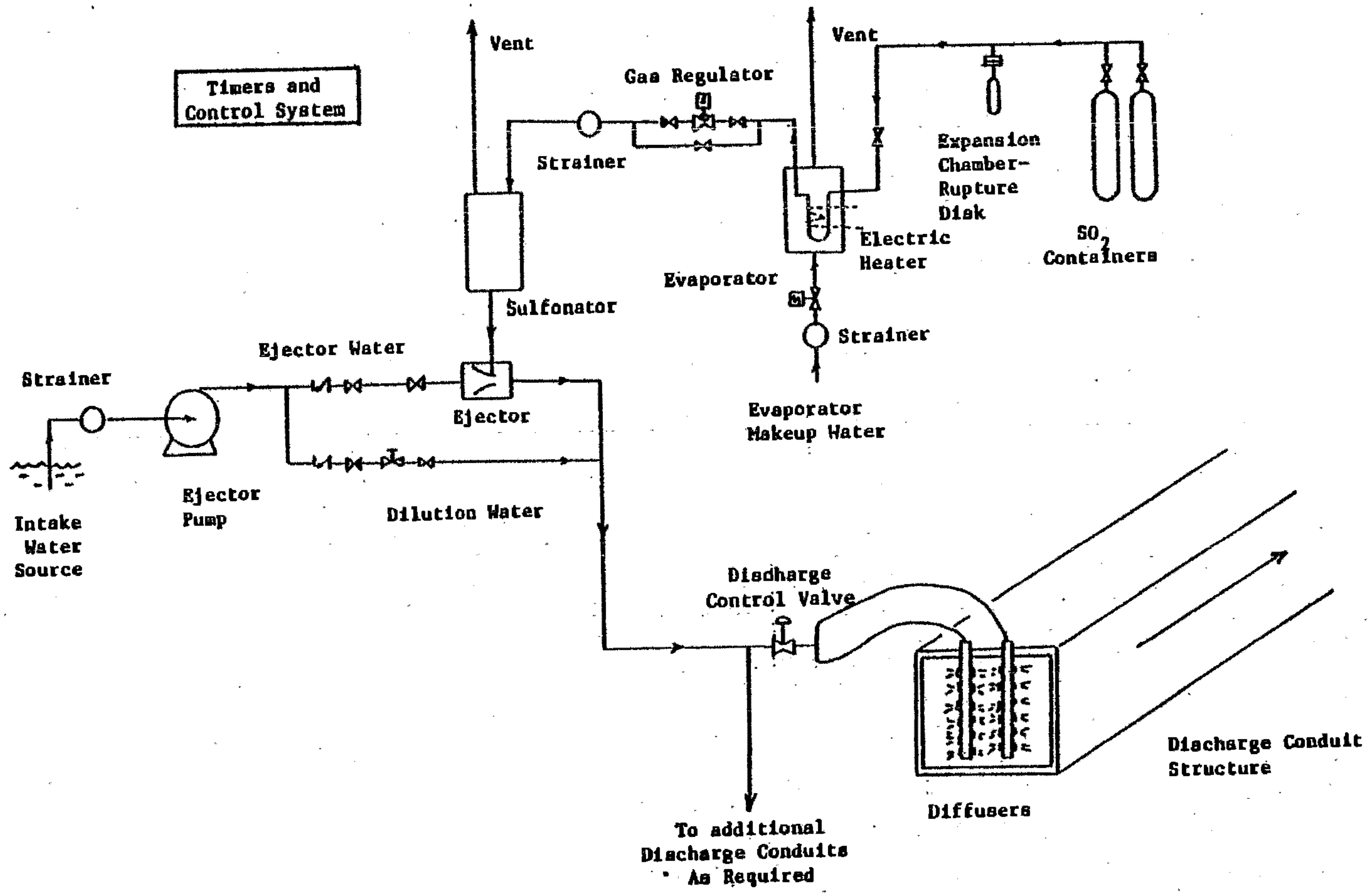

Timers and Control System
Vent
Gas Regulator
Vent
Strainer
Expansion Chamber-Rupture Disk
Electric Heater
SO_2 Containers
Evaporator
Sulfonator
Strainer
Ejector Water
Strainer
Ejector
Evaporator Makeup Water
Intake Water Source
Ejector Pump
Dilution Water
Discharge Control Valve
Discharge Conduit Structure
Diffusers
To additional Discharge Conduits As Required

FIGURE VII - 4

FLOW DIAGRAM FOR DECHLORINATION BY SULFUR DIOXIDE (SO_2) INJECTION

pipe run required to each of the diffusers *can vary significantly from* plant to plant. If the water in the discharge conduit is in turbulent flow, mixing of the injected solution should be complete in approximately ten discharge conduit diameters. In some plants, this length of pipe may not be available between the point at which sulfur dioxide can be injected and the point at which the effluent cooling water enters the receiving source. Adequate mixing can be provided in even these cases by the use of multiple injectors which are commercially available (17).

As stated earlier, the number of diffusers required and the length of the pipe runs to each diffuser vary significantly from plant to plant. Proper diffuser placement is essential for complete dechlorination. In order to provide adequate time for mixing and reaction of the SO_2 with the residual chlorine, it is desirable to locate the diffuser assembly as far upstream from the point of final cooling water discharge as possible. However, no biological fouling control can be expected downstream of the diffuser assembly so in cases where biofouling control is required in the discharge conduit (due to presence of mollusks, asiatic clams, etc.), the diffuser should be located as close to the point of final discharge as possible. In theory, these two opposing constraints are balanced in determining the location of the diffuser assembly. In reality, the location of the diffuser assembly is often fixed by the location of the existing access points in the discharge conduit. Installing the diffuser assembly in an already existing access point (stop log guides, gate shafts) is far less expensive than installing the diffuser assembly by creating a new access point.

A second reason to dechlorinate as far upstream as possible is to minimize the contact time of chlorine with organic matter in the cooling water. Although the kinetics of the formation of chlorinated organics has not been completely defined, it is likely that reducing the chlorine-hydrocarbon contact time will reduce the formation of chlorinated organics.

Chemical Consumption. The amount of SO_2 required to dechlorinate a given cooling water will vary from plant to plant. A stoichiometric analysis of the sulfur dioxide-chlorine residual reaction reveals that 0.9 milligrams of sulfur dioxide are required to remove 1.0 milligrams of residual chlorine (1). Actual operating experience at sewage treatment plant suggests that a sulfur dioxide dose rate of 1.1 milligrams of sulfur dioxide per milligram of total residual chlorine will result in proper system performance (16). As was discussed earlier, the concentration of total residual chlorine in the cooling water effluent will depend on the chlorine dose added and the chlorine demand of the influent water. A high quality influent cooling water will require only a small dose of chlorine to provide the approximately 0.5 mg/l of free available chlorine (FAC) that is required to control biofouling in the condenser. Since a small dose of chlorine was added to the cooling water to begin with, a small dose of sulfur dioxide will be required for dechlorination.

On the other hand, when a poor quality influent cooling water is used (high ammonia concentration), a large chlorine dose will be required to achieve the necessary amount of free residual chlorine. This large chlorine dose may result in a high total residual chlorine concentration which, in turn, would require a large dose of sulfur dioxide to remove the chlorine residual.

In summary, high quality influent water will require small chlorine doses and, in turn, small sulfur dioxide dosages. Low quality, high ammonia influent cooling water is likely to require a high chlorine dose and, therefore, a high sulfur dioxide dose.

Effectiveness. The effectiveness of sulfur dioxide dechlorination has been demonstrated at water and wastewater treatment plants where the technology has been in use since 1926 (17). Municipal treatment plants are able to consistently reduce effluent TRC concentrations to the limit of detection (0.02 mg/l TRC). Of course, a sewage treatment plant is generally dealing with a much lower water flow rate so that a dechlorination contact basin may be used to insure adequate contact time.

Sulfur dioxide dechlorination systems have also been installed or are currently being installed in several United States steam electric plants. A list of these facilities is shown in table VII-2. Plants using both once-through and recirculating cooling water systems are included. At Plant 0611, an involved study was done to determine the effectiveness of dechlorination by sulfur dioxide injection (18). This plant has a once-through cooling system using salt water. Samples were collected from three streams in the plant: the chlorinated condenser outlet, the unchlorinated condenser outlet and the dechlorinated effluent from the SO_2 dechlorination system. The data are presented in tables VII-3, VII-4 and VII-5. In all cases, the total oxidant residual (TOR) in the dechlorinated effluent was below the limit of detection of 0.03 mg/l. Total residual oxidants (TRO), as compared to total residual chlorine (TRC), measures all free oxidants because the bromine in salt water reacts upon chlorination to form bromine residuals which are also active oxidizing compounds. Amperometric titration does not distinguish between chlorine and bromine residuals.

The sampling program conducted at Plant 0611 also included analysis of samples for trihalomethanes. Samples were collected from the same three streams as the TOR samples: the chlorinated condenser outlet, the unchlorinated condenser outlet, and the dechlorinated final effluent. The data indicate that chlorination of a once-through brackish cooling water did result in very small but statistically significant increases in total trihalomethane (THM) concentration. The data also indicated that the dechlorinated effluents contained smaller concentrations of THM's than the non-dechlorinated samples. No mechanism for the decomposition of trihalomethanes by dechlorination is known to exist; the lower THM concentrations in the dechlorinated samples were attributed to sampling error. Thus,

Table VII-2

SULFUR DIOXIDE DECHLORINATION SYSTEMS IN USE OR UNDER CONSTRUCTION AT U.S. STEAM ELECTRIC PLANTS (23)

Plant Code	Plant Capacity (MW)	Cooling Discharge Type	Cooling Discharge Flowrate (MGD)
Plant 4251	130	Blowdown	Not Available
Plant 4107	400	Blowdown	Not Available
Plant 0611	278	Once-Thru	372.2×10^6
Plant 0604	371.4	Once-Thru	348.9×10^6

Table VII-3

CHLORINATED CONDENSER OUTLET FIELD DATA FROM PLANT 0611 (18)

Test No.	Chlorine Dose* (mg/l)	TOR (mg/l)	pH	D.O. (mg/l)
1	0.85	0.052	7.4	3.9
2	0.82	0.027	7.5	3.7
3	0.85	0.093	7.4	4.9
4	0.83	0.200	7.1	4.7
5	0.72	0.269	7.4	5.4
6	0.83	0.178	7.3	5.0
7	0.81	0.122	7.4	5.8
8	0.81	0.168	7.4	5.5
9	0.80	0.213	7.4	5.4
10	0.80	0.217	7.4	5.4
11	0.80	0.206	7.3	5.4
12	0.81	0.225	7.6	7.0
13	0.87	0.243	7.3	5.4
14	0.87	0.265	7.6	5.5
15	0.87	0.315	7.5	5.1
16	0.87	0.281	7.6	5.2
17	0.88	0.320	7.6	4.8
18	0.89	0.339	7.4	5.1
19	0.88	0.331	7.0	5.0
20	0.85	0.277	7.6	5.3
21	0.85	0.289	7.6	5.4
22	0.82	0.259	7.5	5.0
23	0.85	0.304	7.6	5.0
24	0.42	0.140	7.7	5.3
25	0.85	0.306	7.7	5.4
26	0.81	0.270	7.7	5.0
27	0.81	0.256	7.7	5.4
28	0.83	0.322	7.7	5.2

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*Calculated based on chlorine and cooling water flow rates.

Table VII-4

UNCHLORINATED CONDENSER OUTLET FIELD DATA FROM PLANT 0611 (18)

Test No.	TOR (mg/l)	pH	D.O. (mg/l)
1	<0.03	7.6	3.5
2	<0.03	7.3	3.4
3	<0.03	7.5	5.2
4	<0.03	7.4	5.4
5	<0.03	7.2	5.5
6	<0.03	7.4	5.6
7	<0.03	7.4	5.3
8	<0.03	7.4	5.9
9	<0.03	7.4	5.9
10	<0.03	7.4	5.7
11	<0.03	7.4	6.0
12	<0.03	7.0	5.8
13	<0.03	7.4	5.8
14	<0.03	7.5	5.4
15	<0.03	7.5	5.4
16	<0.03	7.7	5.3
17	<0.03	7.7	5.7
18	<0.03	7.4	5.5
19	<0.03	7.7	5.5
20	<0.03	7.7	5.5
21	<0.03	7.6	5.8
22	<0.03	7.6	5.4
23	<0.03	7.7	5.7
24	<0.03	7.7	5.5
25	<0.03	7.7	5.6
26	<0.03	7.6	5.4
27	<0.03	7.7	5.8
28	<0.03	7.7	5.8

Table VII-5

DECHLORINATED EFFLUENT DATA FIELD DATA FOR PLANT 0611 (18)

Test No.	TOR (mg/l)	pH	D.O. (mg/l)
1	<0.03	7.4	3.7
2	<0.03	7.6	3.9
3	<0.03	7.4	4.7
4	<0.03	7.4	5.8
5	<0.03	7.4	5.2
6	<0.03	7.3	4.8
7	<0.03	7.4	5.3
8	<0.03	7.4	5.5
9	<0.03	7.4	5.1
10	<0.03	7.4	5.4
11	<0.03	7.4	5.0
12	<0.03	7.4	5.4
13	<0.03	7.3	5.5
14	<0.03	7.4	4.9
15	<0.03	7.5	5.1
16	<0.03	7.6	5.1
17	<0.03	7.6	5.4
18	<0.03	7.4	5.5
19	<0.03	7.7	5.4
20	<0.03	7.7	5.6
21	<0.03	7.6	5.5
22	<0.03	7.4	5.2
23	<0.03	7.7	5.4
24	<0.03	7.6	5.4
25	<0.03	7.7	5.6
26	<0.03	7.6	5.4
27	<0.03	7.7	4.9
28	<0.03	7.7	5.6

dechlorination is not expected to have a significant effect on the THM concentrations found in once-through cooling water effluent.

In summary, the available data indicate that state-of-the-art SO_2 dechlorination systems can bring effluent TRC concentrations down to the detection limit (approximately 0.03 mg/l). Additional data will be presented shortly on the effectiveness of dry chemical dechlorination systems.

Potential Operating Problems. There are several potential operating problems with sulfur dioxide dechlorination systems. First, since the vapor pressure of sulfur dioxide is lower than chlorine at the same temperature, the sulfur dioxide has a tendency to recondense in the feed lines between the evaporator and the sulfonator. This problem can be controlled by installing continuous strip electric heaters along the feed line piping.

A second potential problem is pH shift in the effluent. The end products of the reaction of sulfur dioxide with hypochlorous acid are sulfuric acid and hydrochloric acid. Both these compounds tend to lower the pH of the effluent water. Since the total dose of sulfur dioxide is, in most cases, quite small and since the water usually has some natural buffering capabilty, the pH shift is usually not significant. A statistical analysis of the pH data collected from each of the three streams at Plant 0611 (tables ViII-3, VII-4, and VII-5) did not indicate that SO_2 dechlorination was causing any statistically significant change in pH.

Excess sulfur dioxide may also react with dissolved oxygen present in the effluent cooling water. This could present a serious problem since dissolved oxygen must be present in water in concentrations of at least 4 mg/l to support many kinds of fish. Sulfur dioxide dechlorination has been practiced at wastewater treatment plants for many years and dissolved oxygen depletion has not been a problem at plants where proper sulfur dioxide dosage control has been practiced. The data collected for dissolved oxygen levels at Plant 0611 (tables VII-3, VII-4, and VII-5) do not indicate that any significant depletion of dissolved oxygen is occurring due to SO_2 dechlorination.

Although some problems exist with sulfur dioxide dechlorination systems, it appears that, with proper equipment maintenance and good process control, sulfur dioxide dechlorination offers an effective method of reducing the discharge of residual chlorine from most powerplants.

Dry Chemical Systems

Several sodium salts of sulfur can be used in dechlorination. These compounds are all purchased in bulk volumes as dry chemical solids. They will, therefore, be referred to hereafter by the generic term "dry chemicals."

Chemical Reactions. One of the dry chemicals commonly used is sodium sulfite (Na_2SO_3). Sodium sulfite reacts with hypochlorous acid as shown in equation 16.

$$Na_2SO_3 + HOCl \rightleftarrows Na_2SO_4 + HCl \qquad (16)$$

The stoichiometry of this reaction is such that 1.775 grams of sodium sulfite are required to remove 1.0 gram of residual chlorine. Sodium sulfite will also react with the chloramines.

A second dry chemical useful in dechlorination is sodium metabisulfite ($Na_2S_2O_5$) which dissociates in water into sodium bisulfite as shown in equation 17.

$$Na_2S_2O_5 + H_2O \rightleftarrows 2NaHSO_3 \qquad (17)$$

The sodium bisulfite then reacts with the hypochlorious acid as shown in equation 18.

$$NaHSO_3 + HOCl \rightleftarrows NaHSO_4 + HCl \qquad (18)$$

Stoichiometrically, 1.34 grams of sodium metabisulfite are required to remove 1.0 gram of residual chlorine. Sodium metabisulfite reduces chloramines through a similar sequence of reactions.

The third commonly used dechlorination dry chemical is sodium thiosulfate ($Na_2S_2O_3$). It reacts with hypochlorus acid as shown in equation 19.

$$Na_2S_2O_3 + 4HOCl + H_2O \rightleftarrows 2NaHSO_4 + 4HCl \qquad (19)$$

The stoichiometric reaction ratio is 0.56 grams of sodium thiosulfate per gram of residual chlorine. Sodium thiosulfate will also reduce chloramines. White (1) does not recommend the use of sodium thiosulfate for dechlorination because it reacts through a series of steps and requires significantly more reaction time than the other dry chemicals. However, sodium thiosulfate has been used at full-scale steam electric plants so it will be discussed here.

Equipment. The equipment required for dechlorination by dry chemical injection is shown in figure VII-5. As indicated in the figure, a complete system includes the following pieces of equipment (11):

- loading hopper - dust collector unit,
- extension storage hopper,
- volumetric feeder,
- solution makeup tank and mixer,
- metering pump,

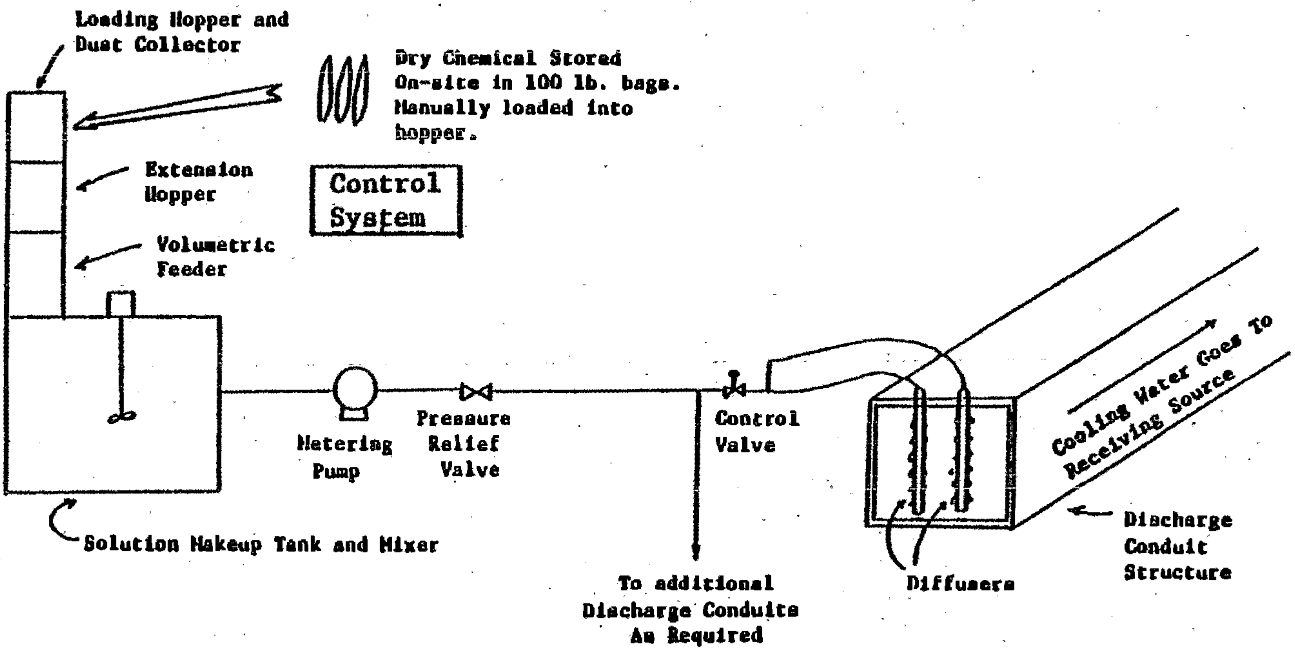
Loading Hopper and Dust Collector
Dry Chemical Stored On-site in 100 lb. bags. Manually loaded into hopper.
Extension Hopper
Control System
Volumetric Feeder
Metering Pump
Pressure Relief Valve
Control Valve
Cooling Water Goes To Receiving Source
Solution Makeup Tank and Mixer
To additional Discharge Conduits As Required
Diffusers
Discharge Conduit Structure

Figure VII-5

FLOW DIAGRAM FOR DECHLORINATION BY DRY CHEMICAL INJECTION

- pressure relief valve, and
- required timers and control system.

Also shown in figure VII-5 is a typical diffuser assembly installation in a discharge conduit.

The chemicals are typically received and stored in 100-pound bags. When necessary, bags are opened and manually dumped into a loading hopper dust collector unit. An extension storage hopper is provided so that bags of chemical need only be loaded on a periodic basis. A volumetric feeder then adds the chemical at a preselected rate into a solution mixing tank. The chemical is mixed with water to form a solution which is then pumped by a metering pump to the required points of injection. If the water in the discharge conduit is in turbulent flow, mixing of the injected solution should be complete in approximately 10 discharge conduit diameters. The dechlorination reaction is generally very rapid but the rate can vary significantly depending on which dry chemical is used. All of the points made earlier about the location of the point of sulfur dioxide injection apply to the point of dry chemical injection. The same is true for the relationship between influent water quality and the required dose of dechlorination chemical.

Effectiveness. Dry chemical injection systems have been or are currently being installed at a number of United States steam electric plants. A list of these facilities is shown in table VII-6. Additional data on the operational practices applied at three of these plants is provided in table VII-7.

These three plants were selected for detailed statistical analysis of their effluent TRC levels over a period of two years. During the two year period, three different chlorination programs were in effect, as follows:

No Controls - 1/77 through 5/77
Chlorine Minimization - 6/11 through 10/77
Dechlorination - 11/77 through 12/78

Thus, dechlorination data from discharge monitoring reports (DMR's) are available for each of the three plants (2603, 2608, 2607) for a period of slightly over one year. As detailed in Appendix C, the dechlorination data were analyzed to determine the 99th percentile of the distribution of daily effluent TRC concentrations. The analysis found 0.14 mg/l TRC to be the concentration below which 99 percent of all grab samples taken during periods of simultaneous chlorination and dechlorination would fall. It is concluded that dry chemical dechlorination can effectively limit the discharge of TRC to concentrations of 0.14 mg/l or lower with 99 percent reliability.

It is important to note that the dry chemical dechlorination systems in use at Plants 2603, 2608, and 2607 are all "make-shift" systems. The equipment used is generally a 55 gallon drum (used as a mix tank)

Table VII-6

DRY CHEMICAL DECHLORINATION SYSTEMS IN USE OR UNDER CONSTRUCTION AT U.S. STEAM ELECTRIC PLANTS* (23)

Plant Code (Capacity)	Cooling System	Agent
Plant 5513 (272 MWe)	Once-thru	Sodium bisulfite
Plant 2601 (615 MWe)	Once-thru	Sodium sulfite
Plant 2607 (325 MWe)	Once-thru	Sodium thiosulfate
Plant 2608 (510 MWe)	Once-thru	Sodium sulfite
Plant 2623 (34 MWe)	Once-thru	Sodium bisulfite
Plant 2603 (1135 MWe)	Once-thru and Recirculating	Sodium sulfite and Sodium thiosulfate

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*In some cases, temporary make shift units were used.

Table VII-7

CHLORINATION/DECHLORINATION PRACTICES (23)

Practice	Plant 2603	Plant 2608	Plant 2607
Dechlorination Chemical	Sodium Sulfite Sodium Thiosulfate	Sodium Sulfite	Sodium Thiosulfate
Dose of dechlorination chemical fed per chlorination period (concentration)	winter .9ppm summer .9 ppm	winter .07 ppm summer .2 ppm	winter .14 ppm summer .3 ppm
Chlorination Chemical	Chlorine Gas	Sodium Hypochlorite	Sodium Hypochlorite
Dose of chlorination chemical fed per chlorination period (concentration of available chlorine)	winter .22 ppm summer 1.06 ppm	winter .04 ppm summer .11 ppm	winter .22 ppm summer .22 ppm
Flow rate of discharge	150,000 gpm	405,000 gpm	214,000 gpm
Reaction time condenser outlet to headwall)	calculated-5 min. actual-4.5 min.	calculated-1-2 min.	calculated-6 min.

with a pump and a hose leading to the condenser outlet. Thus, the apparatus constitutes a minimum of sophistication. It would follow therefore, that properly designed and instrumented dechlorination systems should be capable of achieving much better performance, as demonstrated in other data presented in this section. The data from Plant 0611 (tables VII-3, VII-4, VII-5) which has a properly instrumented SO_2 dechlorination system supports this conclusion. TRC levels in the final effluent from Plant 0611 were consistently below the level of detection.

Potential Operating Problems. Potential problems with dry chemical dechlorination systems include pH shift, and oxygen depletion. Table VII-8 presents pH data from four powerplants with dry chemical dechlorination systems. In these four plants, pH shift was not significant and may have been within the error limits of the instrumentation.

Table VII-9 presents additional data from the same four plants using dry chemical dechlorination. The data indicate that dissolved oxygen depletion in the effluent cooling water is not a problem. In no case was the dissolved oxygen lowered by more than 0.6 mg/l.

In summary, dry chemical dechlorination is an effective method of reducing the discharge of residual chlorine from powerplants. Good process control and proper equipment maintenance are necessary for the system to perform optimally.

Dechlorination by Natural Chlorine Demand

Another form of dechlorination does not require the injection of a reducing agent but, instead, makes optimal use of the reducing compounds naturally present in raw water. These natural dechlorinating agents include all the components of the chlorine demand except ammonia.

Once-Through Cooling Systems. Dechlorination by natural chlorine demand is applied differently for once-through and recirculating plants. In once-through plants the technology essentially consists of placing the point of chlorine injection directly in front of or inside of the condenser inlet box. In an existing plant, this often involves moving the current points of injection from the suction (low pressure) side of the cooling water circulating pumps to the new location near the condenser inlet box (where the water is at high pressure). In a new plant, the chlorination system can be designed to feed into or near the condenser inlet box from the start.

Feeding the chlorine into or near the condenser inlet box may offer any of three distinct advantages depending on plant design. First, less reaction time with the natural chlorine demand of the cooling water will be available before the cooling water reaches the condenser tubes where biofouling control is required. This is because the residence time between the traditional point of chlorine injection-- the suction side of the cooling water pumps-- and the new point of

Table VII-8

EFFECT OF DRY CHEMICAL DECHLORINATION ON PH OF THE COOLING WATER

(EPA Surveillance and Analysis Regional Data)

	pH		
Plant Code	Intake	Chlorinated	Dechlorinated
2603	8.0	8.4	7.2
2608	7.5	8.1	7.9
2607	8.0	7.9	8.0
5513	7.3	7.3	7.2

Table VII-9

EFFECT OF DRY CHEMICAL DECHLORINATION ON DISSOLVED OXYGEN IN COOLING WATER
(EPA Surveillance and Analysis Regional Data)

	Dissolved Oxygen (mg/l)		
Plant Code	Intake	Chlorinated	Dechlorinated
2603	5.8	NA	7.2
2608	8.1	NA	7.5
2607	7.0	NA	6.6
5513	2.2	2.1	1.9

NA - Data not available.

chlorine injection--into or near the inlet condenser box--has been eliminated. A shorter residence time means less of the free chlorine will react with ammonia--to form chloramines of low biocidal activity--and less of the free chlorine will react with other chlorine demand compounds--to form compounds containing no residual chlorine and having little or no biocidal activity. Since less of the free chlorine is being lost to chlorine demand reactions before reaching the condenser tubes, a lower dose of chlorine will be required to achieve the same concentration of free available chlorine in the condenser tubes. Thus, moving the point of chlorine injection may allow a reduction in the chlorine dose required to maintain adequate biofouling control. For this reason, some reports have referred to moving the points of injection as a chlorine minimization technique. The definition of chlorine minimization contained in this document does not include moving the points of injection.

The second major advantage of locating the points of injection at or near the condenser inlet box is that chlorination can then be done sequentially; each condenser or condenser half is chlorinated by itself, one at a time. The effect of chlorinating sequentially is to provide non-chlorinated water for dilution of the chlorinated water stream. Figure VII-6 illustrates a hypothetical powerplant cooling water system; the points of chlorine injection (before and after the movement of the points) are shown. In this example, there are two condensers, each is split into two separate halves. If the cooling water flow rate through each of the condenser halves is equal, then only one quarter of the cooling water flow will be chlorinated at any one time; three quarters of the flow is available for dilution. From simple dilution then, the concentration of residual chlorine in the final discharge effluent will only be one quarter of the concentration present in the exit line from the chlorinated condenser half.

The third major advantage of locating the points of chlorine injection at or near the condenser inlet box is that the nonchlorinated water being used for dilution will also bring about some dechlorination due to the presence of natural chlorine demand compounds in the unchlorinated water. The extent to which dechlorination removes the remaining free chlorine (after dilution) is a function of the quality of the cooling water and the residence time in the cooling water discharge conduit. Any chloramines formed by reaction of chlorine with ammonia will not be decomposed by any of the natural chlorine demand compounds so some residual chlorine will still be present in the final effluent.

In summary, the application of dechlorination by natural chlorine demand in once-through cooling water systems--moving the points of chlorine injection--offers three potential advantages:

1. Less natural dechlorination before the condenser.

2. More unchlorinated water available for dilution.

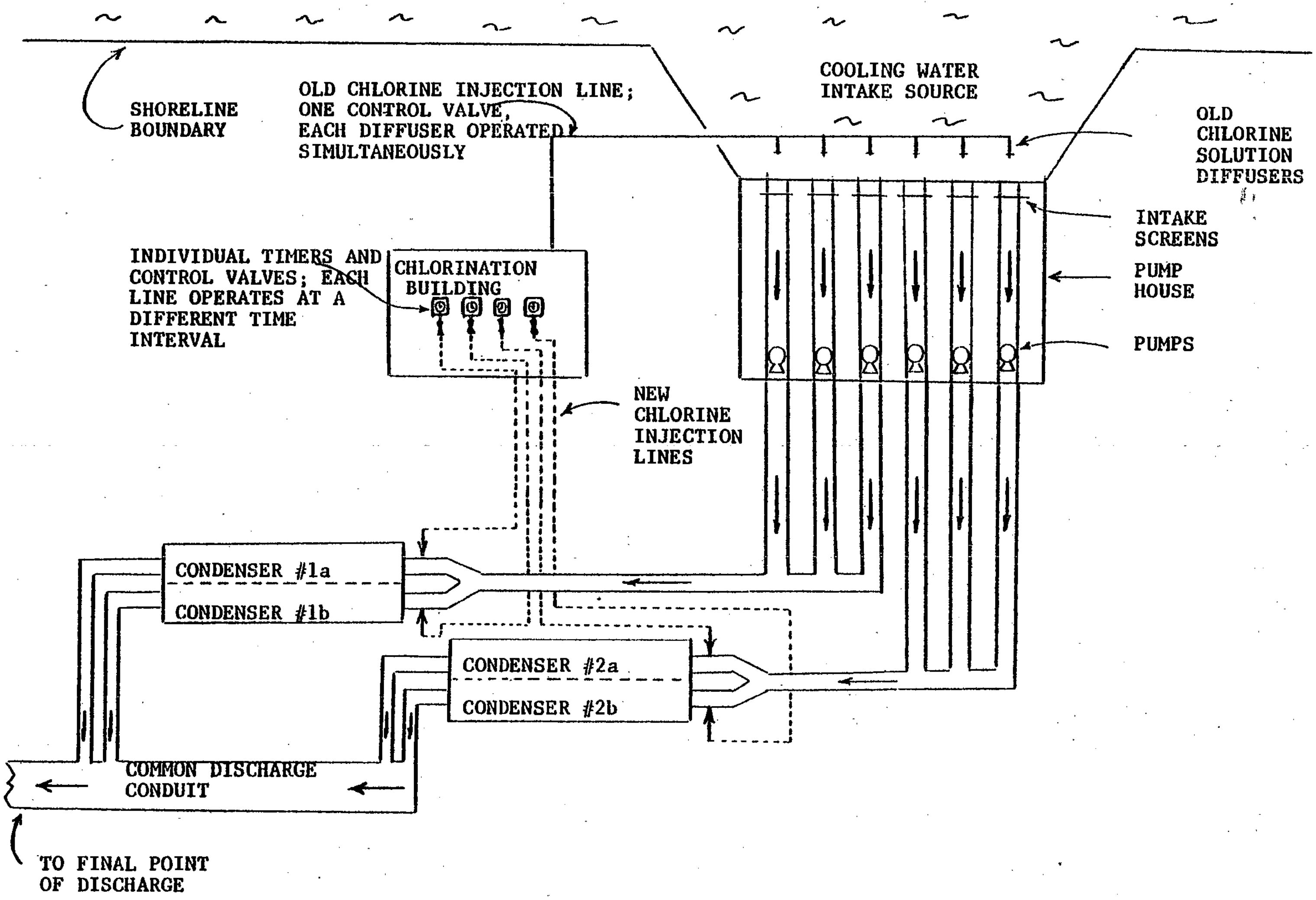
SHORELINE BOUNDARY
OLD CHLORINE INJECTION LINE; ONE CONTROL VALVE, EACH DIFFUSER OPERATED SIMULTANEOUSLY
COOLING WATER INTAKE SOURCE
OLD CHLORINE SOLUTION DIFFUSERS
INTAKE SCREENS
PUMP HOUSE
PUMPS
INDIVIDUAL TIMERS AND CONTROL VALVES; EACH LINE OPERATES AT A DIFFERENT TIME INTERVAL
CHLORINATION BUILDING
NEW CHLORINE INJECTION LINES
CONDENSER #1a
CONDENSER #1b
CONDENSER #2a
CONDENSER #2b
COMMON DISCHARGE CONDUIT
TO FINAL POINT OF DISCHARGE

FIGURE VII - 6

DECHLORINATION BY NATURAL CHLORINE DEMAND IN A ONCE - THROUGH COOLING WATER SYSTEM

3. Some natural dechlorination after the cooling water exits the condenser outlet box.

Recirculating Cooling Systems. In recirculating cooling systems, the application of dechlorination by natural chlorine demand consists of simply modifying the chlorination procedure currently in use at the plant such that blowdown is not discharged during the chlorination period nor during the period of time after chlorine addition stops that residual chlorine is still present in the recirculating cooling water. Once chlorine addition ceases, the natural chlorine demand reactions will bring about a rapid reduction in the residual chlorine concentration present in the recirculating stream. For example, in a study conducted at Plant 0609, it was found that the total residual chlorine concentration in the recirculating water of a cooling tower dropped to zero one and one half hours after chlorine dosage was ceased (20). A program of chlorination was adopted such that the cooling tower blowdown valve was closed during the period of chlorination and left closed for the following three hours. A three hour no-blowdown time period was selected in order to insure complete degradation of the total residual chlorine present in the recirculating cooling water. It is expected that this same kind of operation procedure could be successfully applied to recirculating cooling systems using cooling ponds or canals.

Effectiveness. The effectiveness of dechlorination by natural chlorine demand is extremely site specific. For once-through plants, three factors will tend to increase the effectiveness:

1. The longer the residence time between the present points of chlorine addition and the new points of addition, the more reaction time will be eliminated by moving the points; thus, the larger a reduction in chlorine loss to pre-condenser demand reactions.

2. The larger the number of condensers and the larger the plant megawatt capacity, the more unchlorinated water will be available for dilution, provided all the condenser exit streams are combined before final discharge.

3. The higher the chlorine demand (except ammonia) of the raw cooling water, the more dechlorination will occur upon combination of the chlorinated condenser exit stream with the nonchlorinated streams.

In recirculating cooling systems the following factors play a role in determining the effectiveness of this technology: the amount of chlorine demand in the makeup water, the amount of sunlight entering the tower, and the quality of the air being scrubbed by the tower.

If the implementation of dechlorination by natural chlorine demand is possible at a given plant, there may be very substantial economic advantages to using this technique as opposed to either of the two other dechlorination methods.

Potential Operating Problems. Two potential *operating problems are* immediately apparent when considering dechlorination by natural chlorine demand. First, in once-through cooling systems, there may be a need for biofouling control in the inlet cooling water tunnel(s). If the points of chlorine injection are moved from the entrance to the cooling water tunnels to the condenser inlet box, there may be a problem with biofouling in the inlet cooling water tunnels.

Secondly, in recirculating cooling systems, it may not be possible to shut the blowdown valve for long periods of time on the order of several hours due to the system hydraulic characteristics. This is especially likely to be a problem in large plants using cooling towers where the blowdown flow rate may be on the order of several million gallons per day.

Total Residual Chlorine Control Through Alternative Oxidizing Chemicals

Oxidizing chemicals, other than chlorine, which have been proposed for biofouling control include:

- chlorine dioxide,
- bromine,
- ozone,
- bromine chloride, and
- iodine.

Substitution of the chemicals for chlorine would reduce or eliminate TRC in the cooling water discharge. These chemicals were evaluated and only chlorine dioxide, bromine chloride, and ozone were selected for further consideration.

Chlorine Dioxide

Chlorine dioxide is a gas under standard conditions. At concentrations exceeding 15 to 20 percent, gaseous chlorine dioxide is unstable and, therefore, not suitable for handling in bulk form. As a result, chlorine dioxide is generated on site.

Facility Descriptions. Two methods, the chlorine gas method and the hypochlorite method, are commonly used.

When chlorine gas is dissolved in water, hypochlorous acid and hydrochloric acid are formed:

$$Cl_2 + H_2O \rightleftarrows HOCl + HCl \qquad (20)$$

This is the reaction that occurs in the injector of a chlorination system. The chlorine dioxide biofouling control facility takes the chlorinated water stream from the injector and passes it through a packed column in which it reacts with a sodium chlorite solution to form chlorine dioxide:

$$HOCl + HCl + 2NaClO_2 \rightleftarrows 2ClO_2 + 2NaCl + H_2O \quad (21)$$

The resulting chlorine dioxide solution then enters the cooling water through a diffuser.

A simplified, schematic diagram of a chlorine dioxide biofouling control facility based on the chlorine gas generation method is presented in figure VII-7. The facility contains a complete chlorination system as described in the chlorine biofouling control facility section. In addition, the facility includes a sodium chlorite solution storage container, a metering pump for the sodium chlorite solution, and the packed column. The major component of the chlorine dioxide facility is the chlorination system.

The feed rate of chlorine dioxide to the cooling water is controlled by adjusting the feed rates of the chlorine gas and the sodium chlorite solution to the packed column. The feed rate of chlorine gas is controlled by the chlorinator in the chlorination system. The feed rate of the sodium chlorite solution is controlled by the metering pump. Since the flow of water through the packed column is provided by the booster pump in the chlorination system, the flow remains constant; therefore, changes in the feed rates of chlorine gas and sodium chlorite solution result in changes in the concentration of chlorine dioxide gas in the water entering the diffuser.

When sodium hypochlorite is dissolved in water, hypochlorous acid and sodium hydroxide are formed:

$$NaOCl + H_2O \rightleftarrows HOCl + NaOH \quad (22)$$

Reaction of the hypochlorous acid with a sodium chlorite solution produces chlorine dioxide:

$$2HOCl + 4NaClO_2 + H_2SO_4 \rightleftarrows 4ClO_2 + Na_2SO_4 + 2NaCl + 2H_2O \quad (23)$$

The sodium hydroxide formed in the reaction represented by equation 22 raises the pH of the solution above the optimum for the reaction in equation 23; therefore, sulfuric acid is added to the reaction represented by equation 23 to lower the pH. The reactions in equations 22 and 23 are the basis of the hypochlorite method.

A simplified, schematic diagram of a chlorine dioxide biofouling control facility based on the hypochlorite generation method is presented in figure VII-8. A side stream of cooling water is pumped to a packed column. Sulfuric acid and sodium hypochlorite are added by metering pumps to the water in the pipe between the pump and the column; thus, the reaction in equation 22 has occurred and the pH is at the optimum for the reaction in equation 23 when the water reaches the column. At this point, a sodium chlorite solution is added by a

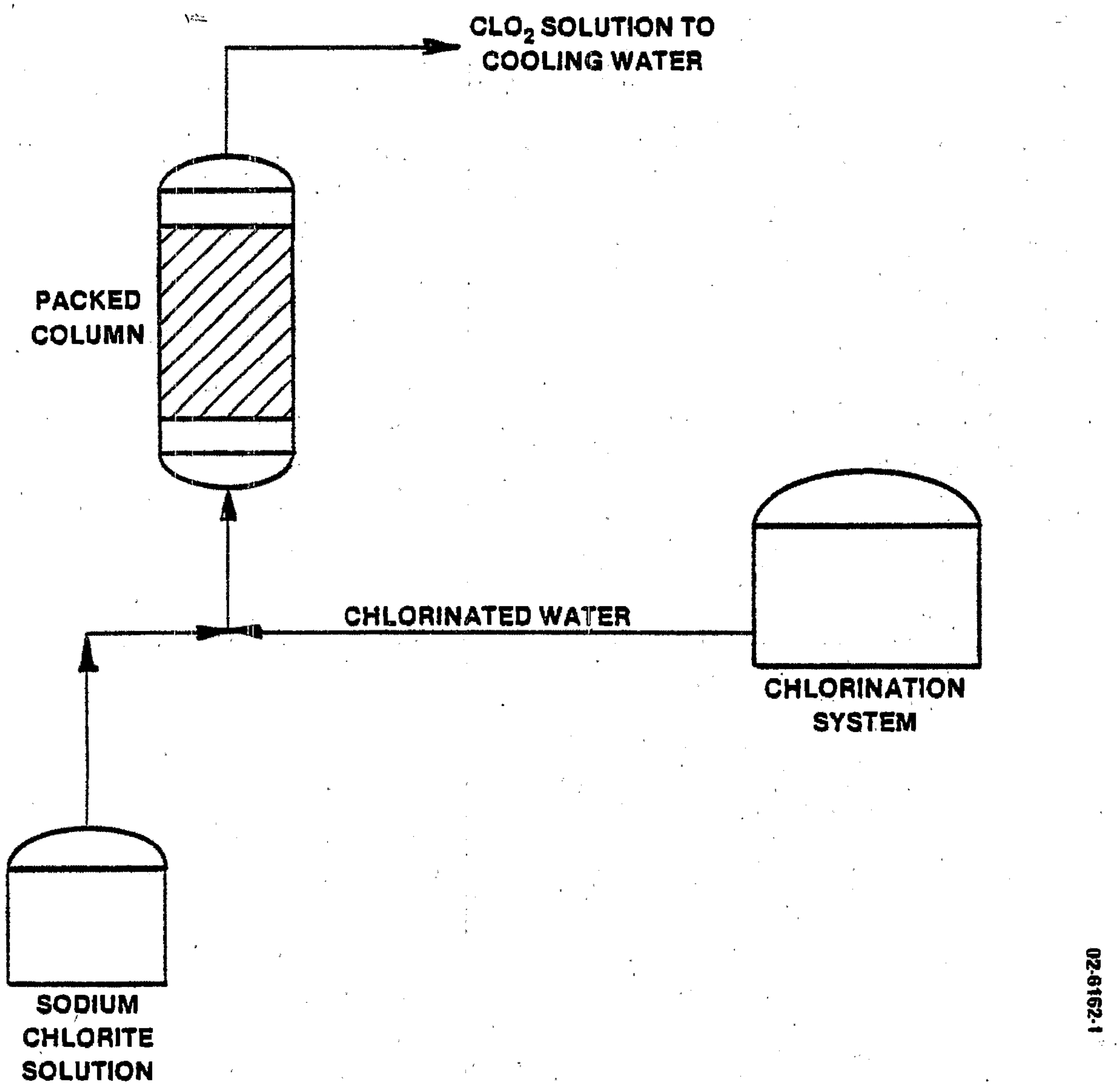
CLO$_2$ SOLUTION TO COOLING WATER
PACKED COLUMN
CHLORINATED WATER
CHLORINATION SYSTEM
SODIUM CHLORITE SOLUTION
02-6162-1

Figure VII-7
Simplified, Schematic Diagram of a Chlorine Dioxide Biofouling Control Facility Based on the Chlorine Gas Method (21)

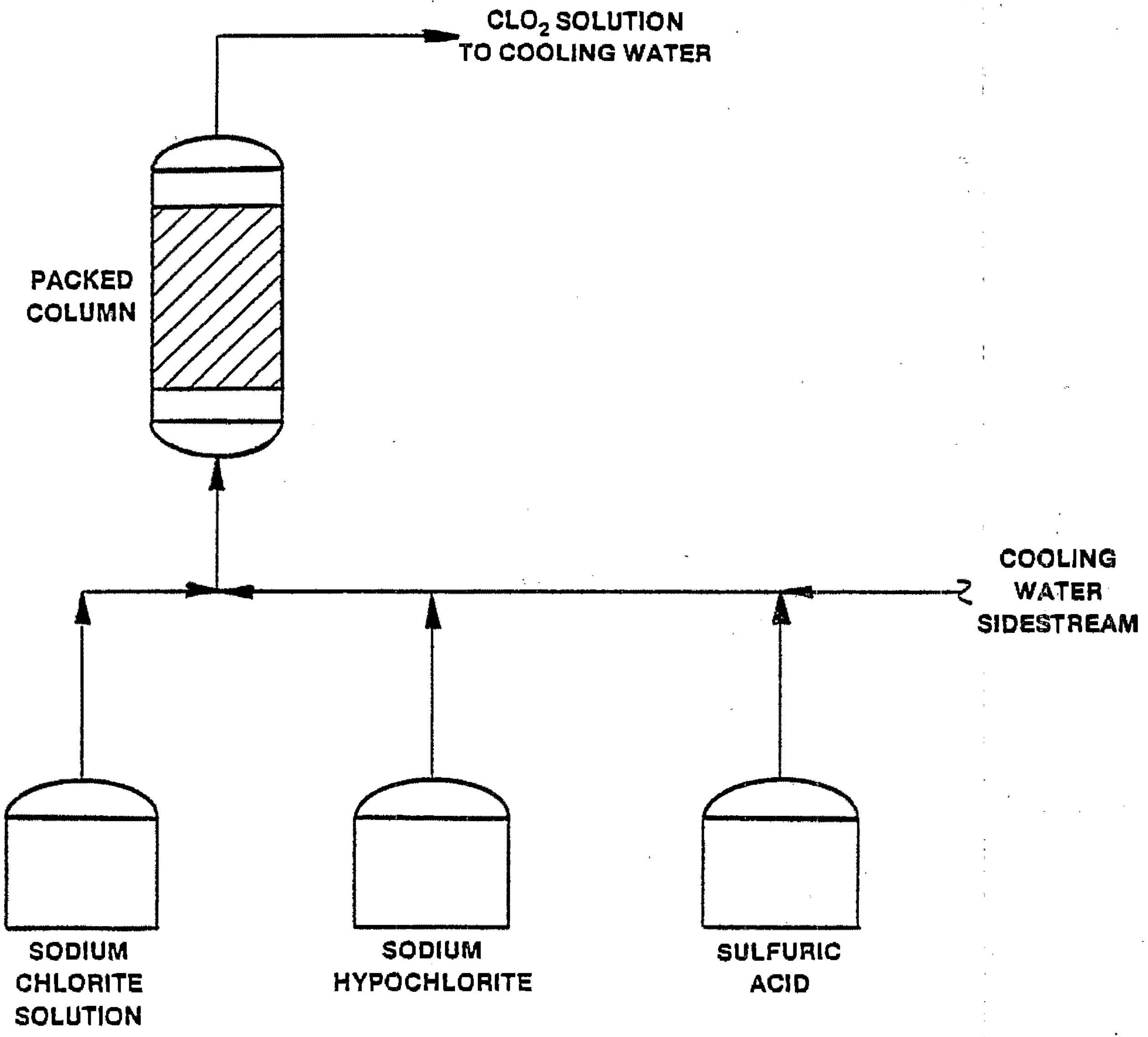
CLO_2 SOLUTION
TO COOLING WATER
PACKED
COLUMN
COOLING
WATER
SIDESTREAM
SODIUM
CHLORITE
SOLUTION
SODIUM
HYPOCHLORITE
SULFURIC
ACID
02-6164-1

Figure VII-8
Simplified, Schematic Diagram of a Chlorine Dioxide Biofouling Control Facility
Based on the Hypochlorite Method (21)

metering pump to the water, and the reaction in equation 23 occurs in the column. The resulting chlorine dioxide solution enters the cooling water through a diffuser. The feed rate of chlorine dioxide to the cooling water is controlled by adjusting the feed rate of the sodium hypochlorite and sodium chlorite solution metering pumps.

Effectiveness. The substitution of chlorine dioxide for chlorine in biofouling control should eliminate all total residual chlorine in the cooling water; however, the addition of excess chlorine in the generation of chlorine dioxide to insure maximum yield could create a total chlorine residual in the cooling water. The determination of the presence or absence of this residual and the concentration if the residual is present, is not possible. All of the methods of determining total residual chlorine are based on the oxidizing power of both free and combined chlorine residuals (14). Chlorine dioxide residuals are also oxidizing agents, though. As a result, any attempt to measure total residual chlorine results in a measurement of both total residual chlorine and chlorine dioxide residuals. No officially accepted method of eliminating the chlorine dioxide residual interference is available (14).

In the absence of data on total residual chlorine in cooling water treated with chlorine dioxide, it was assumed that the concentration of total residual chlorine is zero. The basis for this assumption is fairly sound. The quantity of chlorine dioxide added to the cooling water is much greater than the quantity of chlorine added, and chlorine is a more powerful oxidant than chlorine dioxide (22). Therefore, the limited amount of chlorine is probably consumed by inorganic reducing agents and the biological fouling organisms before chlorine residuals are formed. Although total residual chlorine is probably not present, chlorine dioxide residuals, which are also toxic, are present.

Chlorine dioxide is currently being used for biofouling control in a limited number of steam electric powerplants with once- through cooling water systems and in a single plant with a recirculating cooling water system (23).

Bromine Chloride

Facility Description. A bromine chloride biofouling control facility is identical to a chlorine biofouling control facility except for minor changes required by differences in the physical and chemical properties of bromine chloride and chlorine. Bromine chloride is denser than chlorine, so the handling equipment and scales for the containers are of higher capacity. Bromine chloride exists in equilibrium with bromine and chlorine in both the liquid and the gaseous phases in containers. The vapor pressure of chlorine is higher than the vapor pressures of bromine and bromine chloride; therefore, a chlorine-rich vapor exists in the gas phase in containers. As a result, bromine chloride is always withdrawn from containers as a liquid, and an evaporator is used to convert the liquid to gas. Bromine chloride condenses at a higher temperature than chlorine, so the evaporator is designed to operate at a higher temperature in a bromine chloride facility than in a chlorine facility to prevent condensation of bromine chloride. The design changes consist of using steam or direct electric resistence heating rather than hot water. Bromine chloride attacks both steel and polyvinyl chloride, the materials used in chlorination facilities. As a result, nickel or Monel is substituted for steel and Kynar is substituted for polyvinyl chloride in all parts which are in contact with liquid or vapor bromine chloride (23, 24).

Effectiveness. The substitution of bromine chloride for chlorine in biofouling control should eliminate all total residual chlorine in the cooling water. Although total residual chlorine will not be present, bromine residuals, which are also toxic, will probably be present.

Bromine chloride has been used on a trial basis at three plants with once-through cooling water systems (25, 26, 27), but is not currently being used for biofouling control at any steam electric powerplants (24).

Ozone

Facility Description. An ozone biofouling control facility consists of three systems: the ozone generating system, the gas treating system, and the gas-liquid contacting system.

Ozone is generated on site by passing an oxygen-bearing gas through a high frequency electric field called a corona. A schematic diagram of a corona cell is shown in figure VII-9. The cell consists of two electrodes separated by a narrow gap. One electrode is grounded. A high voltage alternating current is applied to the other electrode. This electrode discharges to the grounded electrode creating a high intensity corona discharge in the gap between the electrodes. The dielectric on the discharging electrode stabilizes the discharge over the entire electrode so that it does not localize in an intense arc. The corona discharge in the gap converts some of the oxygen in the oxygen- bearing gas passing through the gap to ozone. A relatively small amount of the energy in the discharge is utilized to convert oxygen to ozone; consequently, a substantial amount of heat is produced. The low volume of gas passing through the gap cannot dissipate the heat, so the electrodes are cooled by either a liquid or a gas in contact with the side of the electrode opposite the discharge gap. The configuration of the corona cell, the materials of construction, and the cooling method vary with manufacturer (28, 29).

Ozone can be generated from either air or oxygen. In cooling water biofouling control applications, the choice between air and oxygen is based primarily on facility design capacity. For small capacity facilities, air is more economical. For large capacity facilities, oxygen is more economical. The breakpoint between air and oxygen is shown in figure VII-10 as a function of facility capacity expressed as flow and dosage.

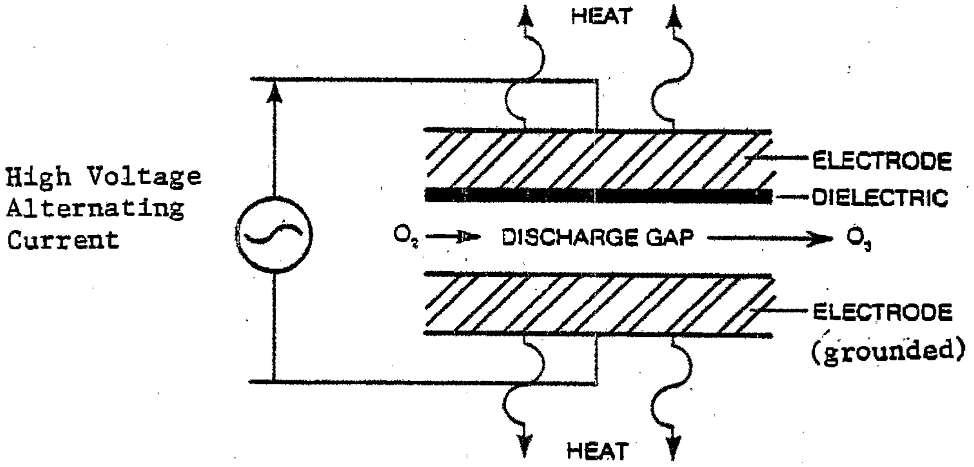
HEAT
High Voltage Alternating Current
ELECTRODE
DIELECTRIC
O_2
DISCHARGE GAP
O_3
ELECTRODE (grounded)
HEAT

Figure VII-9

SCHEMATIC DIAGRAM OF CORONA CELL (28)

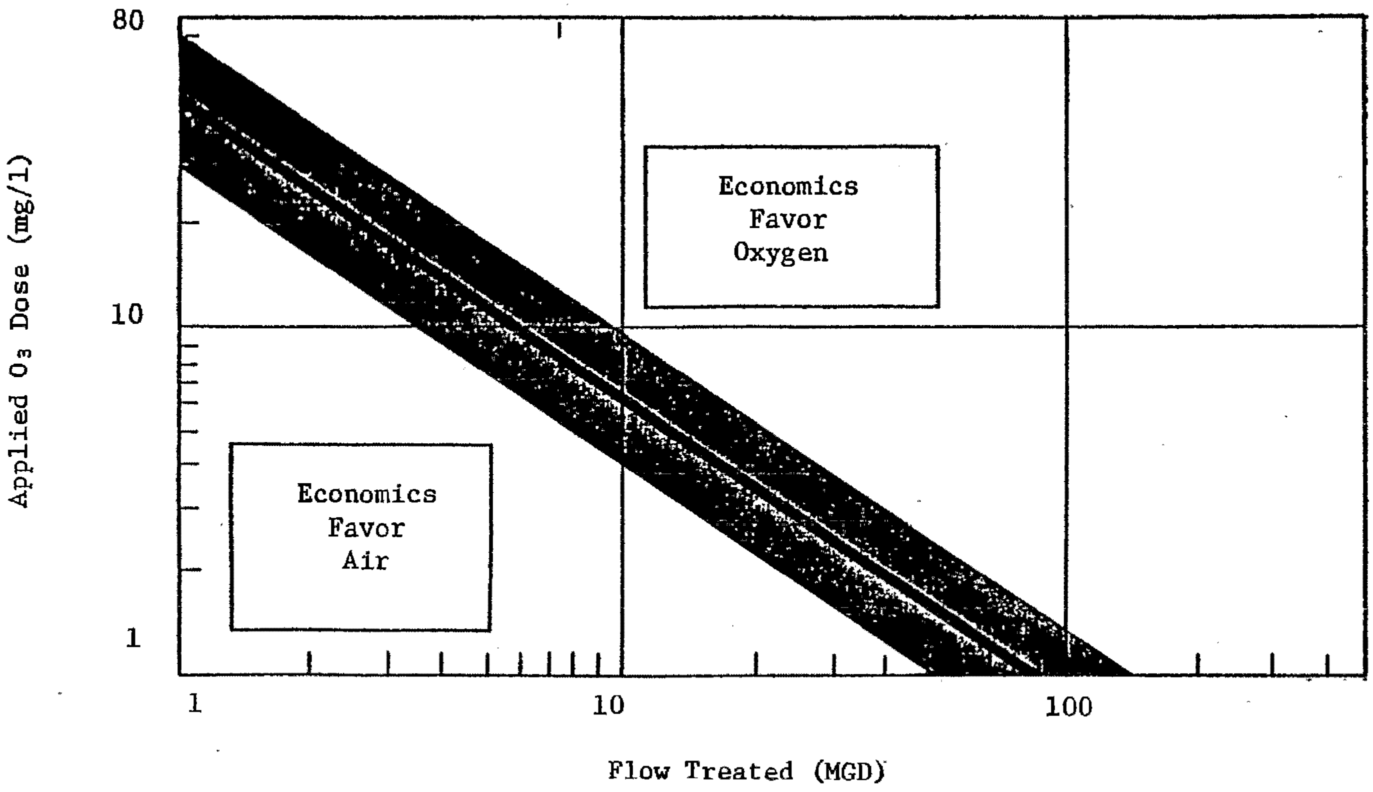

Figure VII-10
EFFECT OF OZONATION FACILITY CAPACITY ON PROCESS CHOICE - OXYGEN VS. AIR (28)

Whether air or oxygen is used, the gas entering the generator must be dry. Moisture is removed from air by lowering its temperature, which causes the water to condense and then passing the air through a desiccant drier. Makeup oxygen comes directly from the oxygen source. Recycled oxygen is extracted from the waste gas from the gas-liquid contacting system. Moisture is removed from the recycled oxygen in the same way it is removed from air.

The three basic methods of supplying makeup oxygen for ozone generation are on site liquid oxygen storage, on site generation by the pressure-swing adsorption process, and on site generation by the cryogenic air separation process. On site liquid oxygen storage requires an insulated tank, an evaporator, and the appropriate piping and valves. The stored liquid is withdrawn and vaporized to gas on demand. The supply of liquid oxygen is replenished periodically by tank truck deliveries from local suppliers. On site storage is the preferred method when makeup requirements are less than 1 ton per day. On site generation by the pressure-swing adsorption process is generally used for oxygen requirements from 1 to 30 tons per day. In this process, air is compressed, cooled to condense moisture, and then passed through an adsorbent that removes carbon dioxide, water vapor, and nitrogen to produce a 90 to 95 percent oxygen gas stream. On site generation by the cryogenic air separation process is generally used for oxygen requirements in excess of 30 tons per day, so this process is rarely used in ozonation systems (28).

The gas-liquid contacting system consists of a closed tank, diffusers, and an ozone decomposition device. Ozone is dispersed in water through diffusers which release the ozone as fine bubbles. The bubbles are dispersed in the water in a closed tank so that the ozone in the gases released from the water can be collected and passed through the ozone decomposition device before release of the gases to the atmosphere or recycle of the gases to the ozone generator. Ozone is fairly insoluble in water; therefore, contacting system designs must optimize the tradeoff between contact time and ozone utilization.

A typical ozonation facility using air to generate ozone is shown in figure VII-11. A typical ozonation facility using oxygen to generate ozone is shown in figure VII-12. The gas treating system, the ozone generating system, and the gas-liquid contacting system are delineated on the diagrams.

Effectiveness. The substitution of ozone for chlorine in biofouling control should eliminate all total residual chlorine in the cooling water. Although total residual chlorine will not be present, other oxidant residuals, which are also toxic, will probably be present.

Ozone is not currently being used for biofouling control at any steam electric powerplant. Ozone has been used on a trial basis for biofouling control at one plant (23).

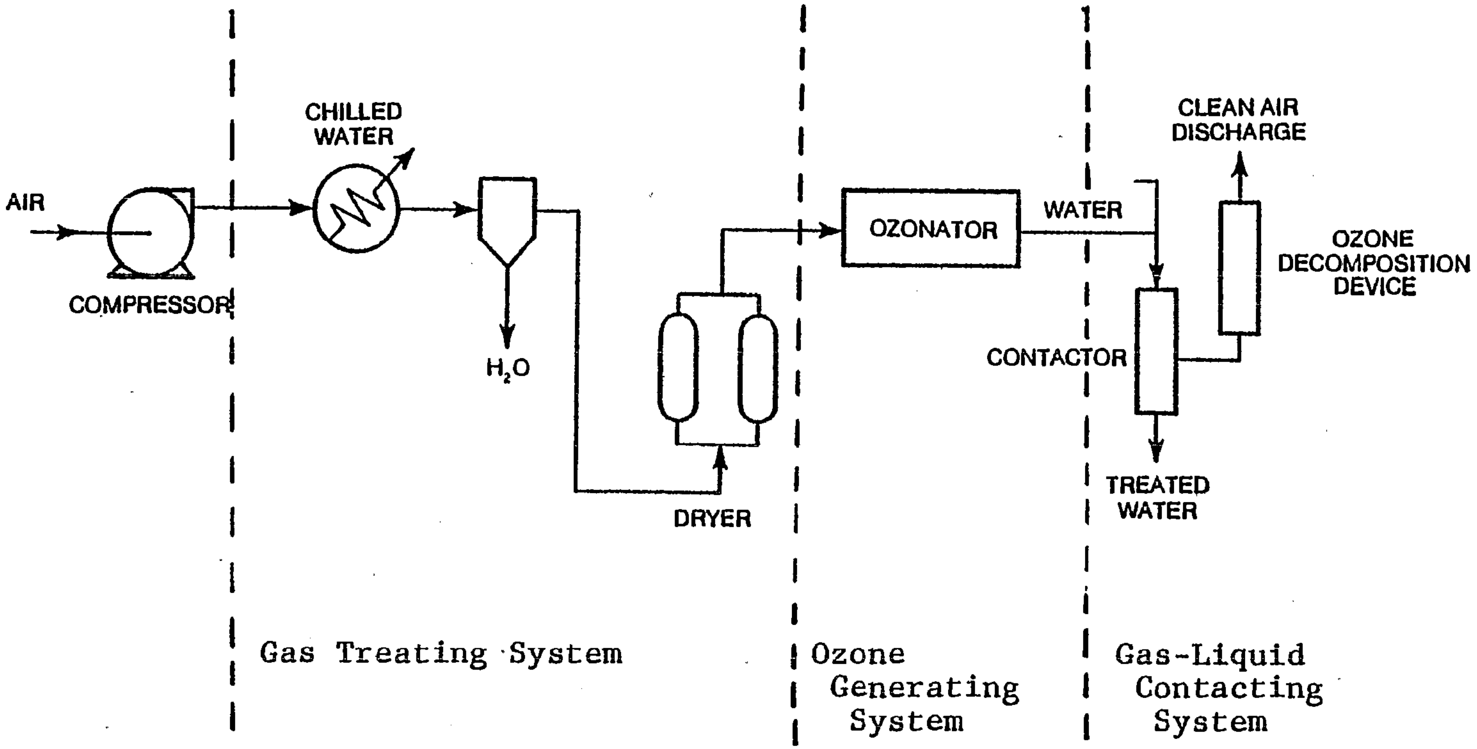
AIR
COMPRESSOR
CHILLED WATER
H_2O
DRYER
OZONATOR
WATER
CLEAN AIR DISCHARGE
OZONE DECOMPOSITION DEVICE
CONTACTOR
TREATED WATER
Gas Treating System
Ozone Generating System
Gas-Liquid Contacting System

Figure VII-11
OZONATION FACILITY USING AIR TO GENERATE OZONE (28)

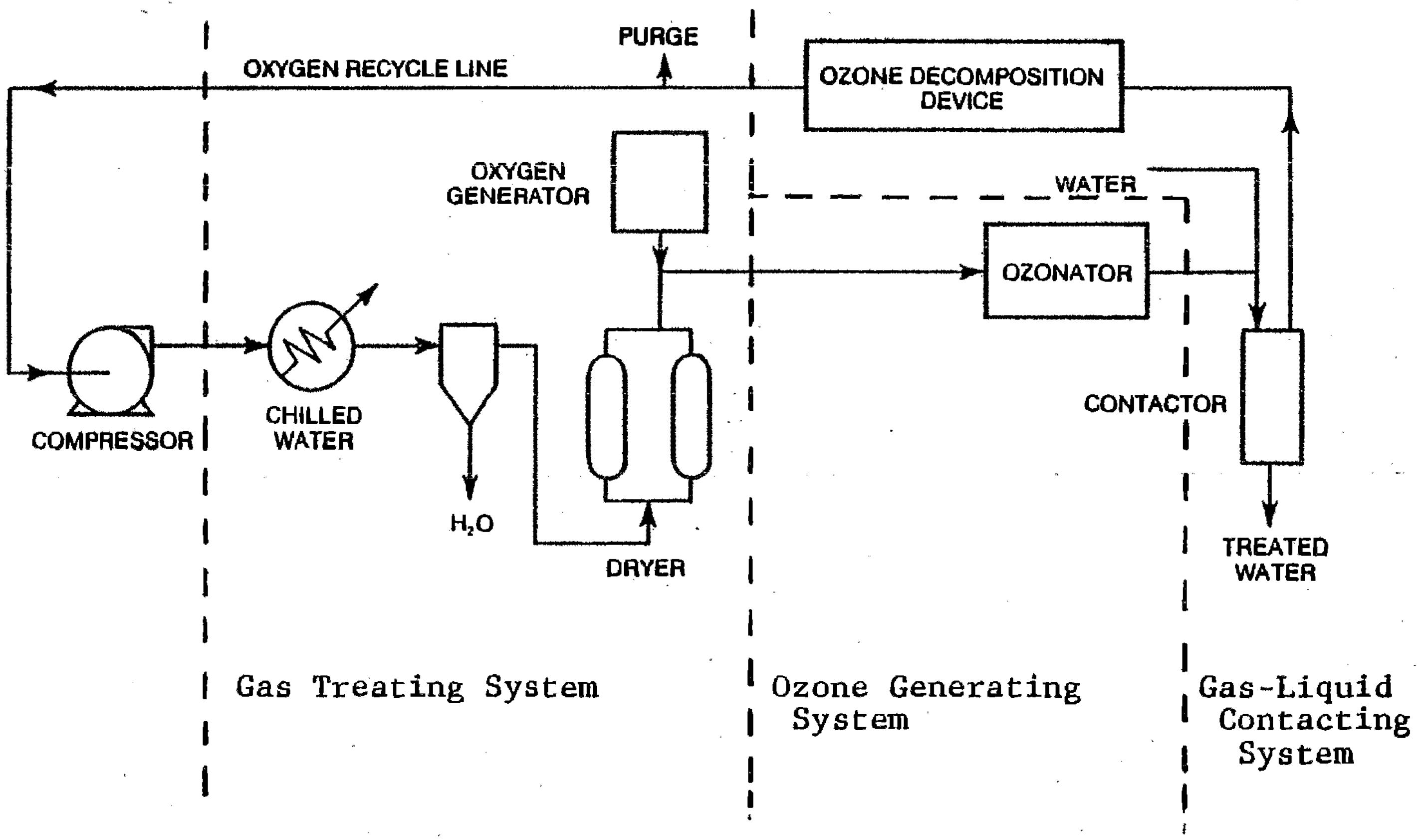
PURGE
OXYGEN RECYCLE LINE
OZONE DECOMPOSITION DEVICE
OXYGEN GENERATOR
WATER
OZONATOR
COMPRESSOR
CHILLED WATER
H_2O
DRYER
CONTACTOR
TREATED WATER
Gas Treating System
Ozone Generating System
Gas-Liquid Contacting System

Figure VII-12

OZONATION FACILITY USING OXYGEN TO GENERATE OZONE (28)

Total Residual Chlorine Control Through Mechanical Cleaning

Mechanical means of cooling system cleaning can be used in place of chemical antifoulants. The most obvious method is manual cleaning which requires long plant downtime. Two types of automatic mechanical condenser cleaning systems, which can be used during normal plant operations, are the Amertap and American M.A.N. systems. Diagrams showing the major components of each of these systems are presented in figures VII-13 and VII-14. The Amertap system is the most common type of automatic mechanical cleaning system. By circulating oversize sponge rubber balls through the condenser tubes with the cooling water, the inside of the condenser tubes are wiped. The balls are collected in the discharge water box by screens and repumped to the inlet of the condenser for another pass through the system. They can be used on an intermittent or continuous basis. The American M.A.N. system uses flow drive brushes which are passed through the condenser tubes intermittently by reversing the flow of condenser cooling water. The brushes abrasively remove fouling and corrosion products. Between cleaning cycles, the brushes are held in baskets attached at both ends of each tube in the condenser.

The Amertap and, to a lesser extent, the American M.A.N. system have been reasonably successful in maintaining condenser efficiency and reliability. Some problems are abrasion and grooving of condenser tubes, and, in some cases, the systems themselves become fouled and must be cleaned.

Priority Pollutants Control Through Alternative Corrosion and Scaling Control Chemicals

The principal control technology available to eliminate the discharge of priority pollutants as a result of the use of corrosion and scale control agents is the substitution of corrosion and scaling control agents which do not contain priority pollutants. Most powerplants usually purchase the chemicals they need for corrosion and scaling control from vendors as prepackaged mixtures. The exact composition of these "proprietary" mixtures is confidential but a partial listing of some of the commonly used mixtures which do contain priority pollutants is given in table VII-10 (31). At least one vendor is now offering a corrosion and scaling control mixture that contains neither zinc nor chromium and has proven very effective in several full scale test programs in various industrial applications (32).

Priority Pollutant Control Through Alternative Non-Oxidizing Biocides

Many steam electric powerplants use non-oxidizing biocides instead of or in conjunction with the oxidizing biocides. The non-oxidizing biocides are also effective in controlling biofouling but do so through mechanisms other than direct oxidation of cell walls.

A list of most of the commonly used oxidizing biocides is presented in table VII-11 (33, 34). Note that there are really two kinds of oxidizing biocides. The first group are appropriate for use in large

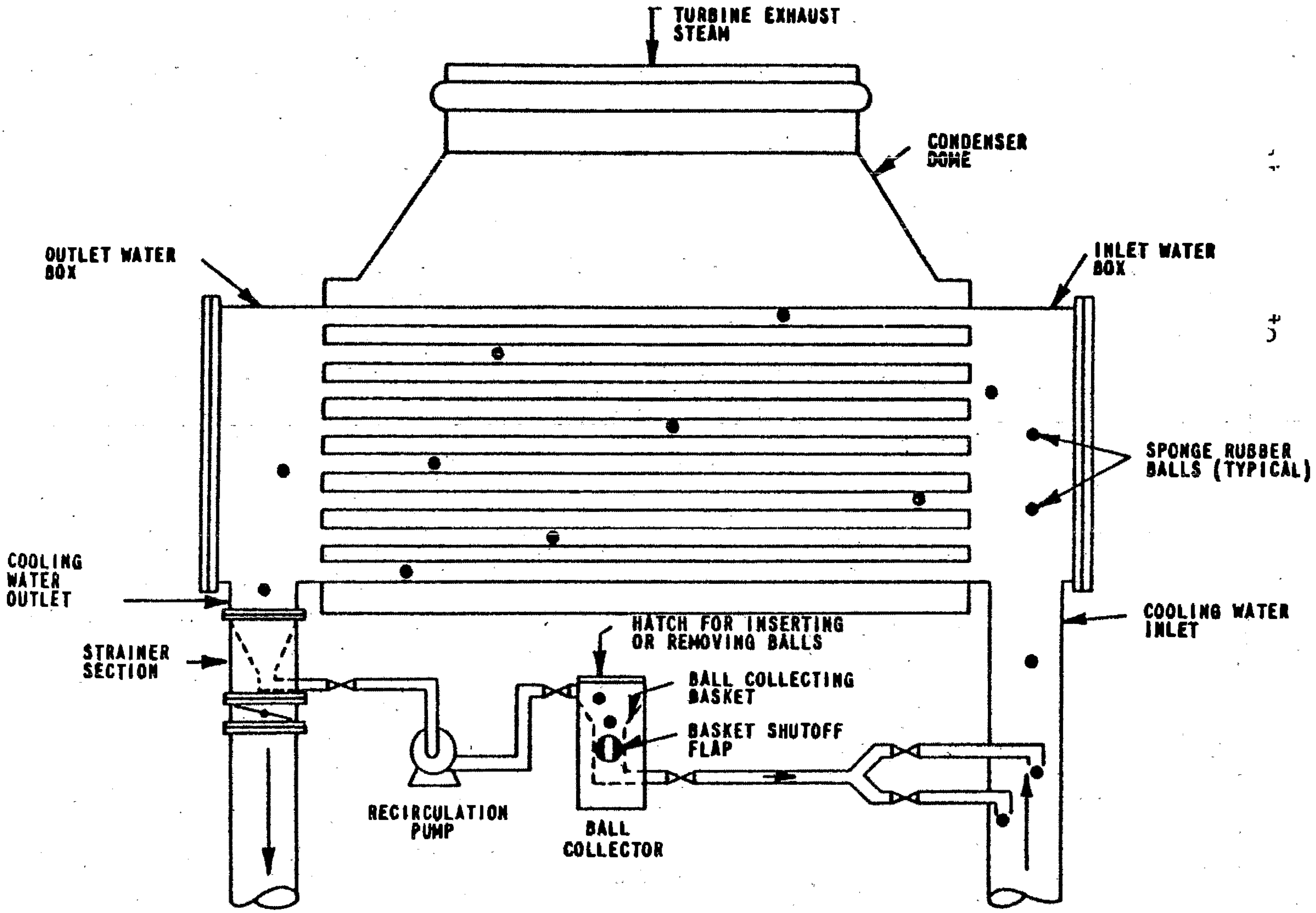
TURBINE EXHAUST STEAM
CONDENSER DOME
OUTLET WATER BOX
INLET WATER BOX
SPONGE RUBBER BALLS (TYPICAL)
COOLING WATER OUTLET
COOLING WATER INLET
STRAINER SECTION
HATCH FOR INSERTING OR REMOVING BALLS
BALL COLLECTING BASKET
BASKET SHUTOFF FLAP
RECIRCULATION PUMP
BALL COLLECTOR

FIGURE VII -13

SCHEMATIC ARRANGEMENT OF AMERTAP TUBE CLEANING SYSTEM (30)

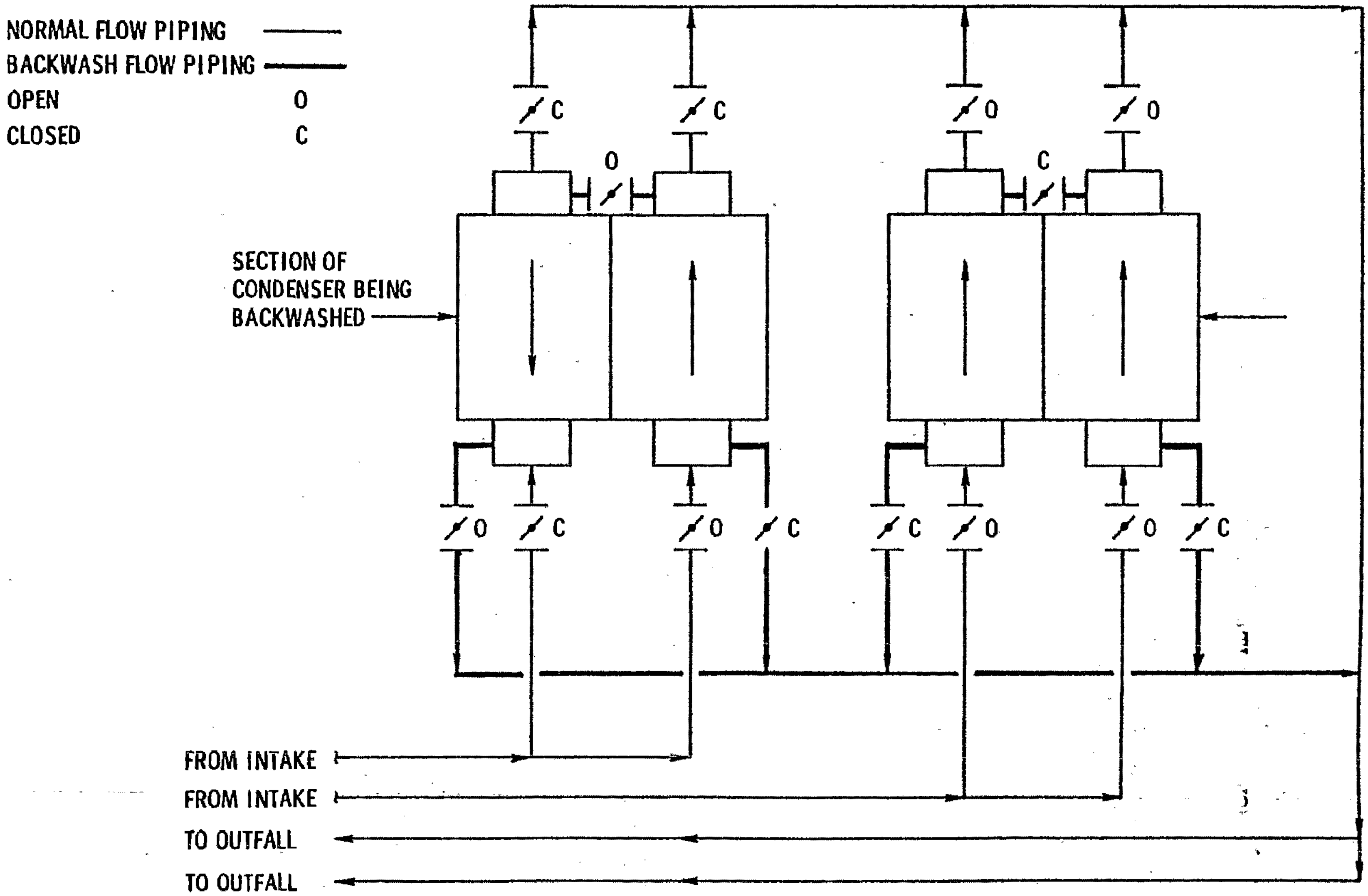
NORMAL FLOW PIPING
BACKWASH FLOW PIPING
OPEN O
CLOSED C
SECTION OF CONDENSER BEING BACKWASHED
C
C
O
O
O
C
O
C
O
C
C
O
C
O
O
C
FROM INTAKE
FROM INTAKE
TO OUTFALL
TO OUTFALL

FIGURE VII -14

SCHEMATIC OF M.A.N. SYSTEM REVERSE FLOW PIPING (30)

Table VII-10

CORROSION AND SCALING CONTROL MIXTURES KNOWN TO CONTAIN PRIORITY POLLUTANTS (31, 32)

Compounds Known to Contain Priority Pollutants	Specific Priority Pollutants Contained in Product
NALCO CHEMICALS	
25L	Copper
38	Chromium
375	Chromium
CALGON CHEMICALS	
CL-70	Zinc Chloride
CL-68	Sodium Dichromate, Zinc Chloride
BETZ CHEMICALS	
BETZ 40P	Chromate and Zinc Salts
BETZ 403	Chromate and Zinc Salts
Dianodic 191	Chromate and Zinc Salts
HERCULES CHEMICALS	
CR 403	Zinc Dichromate, Chromic Acid
BURRIS CHEMICALS	
Sodium Dichromate	Sodium Dichromate

Table VII-11

COMMONLY USED OXIDIZING BIOCIDES (33, 34)

Group A - Appropriate for Use in Large Scale Applications, Require Expensive Feed Equipment

- Bromine chloride
- Chlorine
- Chlorine dioxide
- Ozone

Group B - Appropriate for Use on Intermittent Basis or in Small Systems, May Not Require Expensive Feed Equipment

- Ammonium persulfate
- Bromine
- Calcium chlorite
- Calcium hypochlorite
- Dibromonitrilopropionamide
- 2,2-dichlorodimethyl hydantoin
- Iodine
- Potassium hydrogen persulfate
- Potassium permangnate
- Sodium chlorite
- Sodium dichloroisocyanurate
- Sodium dichloro-s-triazinetrione
- Sodium hypochlorite
- Trichloroisocyanuric acid

NOTE: None of these compounds are priority pollutants.

scale applications and require expensive feed equipment. These compounds have all been thoroughly discussed earlier and no further discussion will be presented here.

The second group of oxidizing biocides are commonly purchased from suppliers as a liquid or solid in small containers (i.e., 50 gallon drums, 100 pound bags). These biocides are fed using relatively simple feed equipment (solution tank, mixer, pump, diffuser) and in some cases are simply dumped into the influent lines to the cooling system. Note that many of these compounds contain chlorine which is released upon solution in water to form hypochlorous acid (free available chlorine). The use of chlorine in this form will create the same problems as injection of chlorine gas, the only difference being the method in which the chlorine was introduced to the system. Plants using the "chlorine bearing" compounds will have to meet the same effluent standards as plants injecting chlorine gas. Both chlorine minimization and dechlorination are technologies available to help a plant meet total residual chlorine limitations.

A third possible technology is the substitution of a "nonchlorine bearing" oxidizing biocide which may offer similar biofouling control but will not result in the discharge of residual chlorine. For example, a plant currently using calcium hypochlorite could switch to dibromonitrilopropionamide (DBNPA) and avoid the discharge of residual chlorine altogether.

Another substitution available to the plant is to use a nonoxidizing biocide instead of an oxidizing biocide. A list of the commonly used non-oxidizing biocides is presented in table VII-12. as the table shows, a large diversity of products have been used for this purpose. An advantage that non-oxidizing biocides have over their oxidizing counterpart is their slow decay. Oxidizing biocides are, by design, very reactive compounds. As a result, the oxidizing biocides react with many contaminants present in the cooling water and rapidly decay to relatively non-toxic compounds. The non-oxidizing biocides are, by design, very toxic materials which react selectively with microorganisms and other life forms. They may decay very slowly once released to the environment and thus pose a substantial environmental hazard.

Many of the non-oxidizing biocides are priority pollutants. If a compound is a known priority pollutant it is marked with an asterisk to the left of the compound name. Since there are many non-priority pollutant, non-oxidizing compounds readily available on the marketplace, it is not recommended that priority pollutants be used for this purpose.

Before searching for a substitute for the current biocide a plant is using, careful examination should be given for the need of biocides at all, especially non-oxidizing biocides. Once-through cooling systems located in areas where biofouling is a problem should be able to achieve adequate biofouling control with chlorine or perhaps one of the other "large-scale" oxidizing biocides. If additional control

Table VII-12

COMMONLY USED NON-OXIDIZING BIOCIDES (33, 34)

*Acid copper chromate

*Acrolein

n-alkylbenzyl-N-N-N-trimethyl ammonium chloride

n-Alkyl (60% C_{14}, 30% C_{16}, 5% C_{12}, 5% C_{18}) dimethyl benzyl Ammonium chloride

n-Alkyl (50% C_{12}, 30% C_{14}, 17% C_{16}, 3% C_{18}) dimethyl ethylbenzyl ammonium chloride

n-Alkyl (98% C_{12}, 2% C_{14}) dimethyl-1-naphthylmethyl ammonium chloride

alkylmethylbenzylammonium lactate

Alkyl-9-methyl-benzyl ammonium chloride

n-Alkyl (C_6 - C_{18}) - 1,3-Propanediamine

*Arsenous Acid

*Benzenes

Benzyltriethylammonium chloride

Benzyltrimethylammonium chloride

Bis-(tributyltin) oxide

Bis-(trichloromethyl) sulfone

Bromonitrostyrene

Bromostyrene

2-bromo-4-phenylphenol

*Carbon tetrachloride

Cetyldimethylammonium chloride

Chloro-2-phenylphenol

2-chloro-4-penylphenol

*Chromate

*Copper Sulfate

*Cromated copper arsenate

*Cresote

*Cyanides

3,4-dichlorobenzylammonium chloride

Table VII-12 (Continued)

COMMONLY USED NON-OXIDIZING BIOCIDES (33, 34)

*2,4-dichlorophenol
Dilauryldimethylammonium chloride
Dilauryldimethylammonium oleate
Dimethyltetrahydrothiadiazinethione
Disodium ethylene-bis-(dithiocarbamate)
Dodecyltrimethylammonium chloride
Dodecyl dimethyl ammonium chloride
Dodecyl guanidine acetate and hydrochloride
Isopropanol
*Lactoxymercuriphenyl ammonium Lactate
Lauryldimethyl-benzyldiethylammonium chloride (75%)
Methylene bisthiocyanate
Octadecyltrimethylammonium chloride
*Phenylmercuric triethanol-ammonium lactate
*Phenylmercuric trihydroxethyl ammonium lactate
o-phenylphenol
Poly-(oxyethylene (dimethylimino) ethylene-(dimethylimino) ethylene dichloride)
Sodium dimethyldithiocarbamate
*Sodium pentachlorophenate
*Sodium trichlorophenate
2-tertbutyl-4-chloro 5-methyl phenol
2,3,4,6-tetrachlorophenol
Trimethylammonium chloride
*Zinc salts

In addition to the above chemicals the following may be present as solvents or carrier components:

Dimethyl Formamide
Methanol

Table VII-12 (Continued)

COMMONLY USED NON-OXIDIZING BIOCIDES (33, 34)

Ethylene glycol monomethyl ether
Ethylene glycol monobutyl ether
Methyl Ethyl Ketone
Glycols to Hexylene Glycol
*Heavy aromatic naphtha
Cocoa diamine
Sodium chloride
Sodium sulfate
Polyoxyethylene glycol
Talc
Sodium Aluminate
Mono chlorotoluene
Alkylene oxide - alcohol glycol ethers

NOTE: *Indicates the compound is known to contain a priority pollutant. Some of the other compounds may degrade into priority pollutants but no data was available to make a definite determination.

seems needed, the plant should first attempt modifications of its current biocide program, i.e., change the dosage, frequency, etc. Another possibility is the periodic use of a dispersant or "chlorine helper" which is a specially formulated mixture designed to increase the penetration of chlorine, especially into existing thick slime films. A study was conducted at Plant 5004 over a three year period during which the dosage rate of chlorine and a "chlorine helper" were varied. The "chlorine helper" was found to significantly increase the cleanliness factor of the condenser tubes and helped to keep mud and silt from settling out in the cooling systems (35). The success of the use of a "chlorine helper" is likely to be extremely site specific and depend on water quality, system design and other factors.

Recirculating plants also often operate with the use of chlorine alone. In those recirculating plants using cooling towers with wood fill, a special biofouling problem exists. It is only in these systems in which the use of non-oxidizing biocides is really justified (23). The problem is that the wood fill is susceptible to fungal attack in the center of the boards. Chlorine doses high enough to provide microbial control at the center of the boards would result in the delignification of the lumber and destroy the wood's structural strength. Thus, a nonoxidizing biocide offers a perfect solution. For this reason, lumber used in cooling tower fill is often pre-treated with a non-oxidizing biocide. Pentachlorophenate and various trichlorophenates are frequently used for this purpose (33). Both pentachlorophenate and the trichlorophenates are priority pollutants.

Vendors of non-oxidizing biocides have indicated that nonpriority pollutant non-oxidizing biocides are available at approximately the same cost as their priority pollutant analogs (33). Thus, when the use of a non-oxidizing biocide is required, there is no cost penalty in using a compound that is not a priority pollutant. The use of non-oxidizing biocides in once-through cooling systems is likely to be prohibitively expensive and represents a serious environmental hazard and is therefore, not recommended.

Priority Pollutant Control Through Replacement of Asbestos Cooling Tower Fill

The technology evaluated to control the discharge of asbestos fibers in cooling tower blowdown is replacement of existing asbestos fill material. Existing asbestos cement fill is taken out of the tower and replaced with wood, PVC, or ceramic tiles. This is a straightforward disassembly and reassembly construction procedure. The tower is, of course, out of service during this construction activity.

Ash Handling

Systems for handling the products of coal combustion by hydraulic or pneumatic conveyors have been used for 50 years or more. With the advent of larger steam generation units, larger ash handling systems have been built with heavier components to cope with the increased loads. Powerplant refuse, which can be classified as ash, falls into four categories (36):

1. Bottom ash (dry or slag)--material which drops out of the main furnace and is too heavy to be entrained with the flue gases;

2. Fly ash--finer particles than bottom ash which are entrained in the flue gas stream and are removed downstream via dust collecting devices such as electrostatic precipitators, baghouses, and cyclones;

3. Economizer and air preheater ash--coarser particles which drop out of flue gases as a result of changes in direction of the flue gas; and,

4. Mill rejects, or pyrites--variety of coarse, heavy pieces of stone, slate, and iron pyrite which are removed from coal during preparation stages (at plants which clean the coal prior to use).

Economizer and air preheater ashes are usually collected in hoppers and transported in conjunction with fly ash to a disposal site; thus, fly ash transport systems are considered to apply to the economizer and preheater ash as well. Mill rejects are wastes encountered in coal preparation which is usually performed off site; therefore, mill reject transport systems are treated as off site operations and are not addressed in this discussion. As a result, only bottom ash and fly ash handling systems are considered in this subsection.

Statistics for 1975 indicate that approximately 410 million tons of coal were burned, producing nearly 41 million tons of fly ash and 22 million tons of bottom ash and boiler slag (37). As coal use increases to replace the dwindling supplies of other fuels used for generating electric power, the amounts of fly ash and bottom ash requiring proper disposal will also increase. Perhaps the most environmentally acceptable and economically attractive method of disposal is through utilization as a raw material in the manufacture of new products. Recently fly ash and other coal residues have found uses such as lightweight aggregates for construction, structural fills, embankments, or low-cost highway base mixes. Ash also has been successfully used as a soil amendment, in fire-control or fire-abatement procedures, and for treatment of acid mine drainage. Since ash is typically high in concentrations of many metals such as copper, vanadium, aluminum, chromium, manganese, lead, zinc, nickel, titanium, magnesium, strontium, barium, lithium, and calcium, it may serve as an important source of these metals in the near future (38). Thus far, however, the use of fly ash and bottom ash in manufacturing has been relatively small, only 16.3 percent in 1974 (38); therefore, the major portion of the fly ash and bottom ash resulting from coal combustion must be disposed of.

Fly Ash

The treatment and control technologies applicable to fly ash handling systems are:

1. dry fly ash handling;

2. partial recirculation fly ash handling; and

3. physical/chemical treatment of ash pond overflows from wet, once-through systems.

Dry Systems

Dry fly ash handling systems are pneumatic systems of the vacuum or pressure type. Vacuum systems use a vacuum, produced by ejectors or mechanical blowers, to provide the necessary air flow to convey ash from the electrostatic precipitator (ESP) hoppers to its destination point, i.e., a dry storage silo or landfill. Pressure systems, on the other hand, make use of pressure blowers to provide the required air flow for ash conveying. In general, a vacuum system is more limited in conveying distance than a pressure system; thus, vacuum systems are generally not used for systems covering distances greater than 500 to 700 feet (39). Controls for a vacuum system are generally simpler than those for a pressure system. This can be advantageous for systems which have a large number of ash hoppers, e.g., 35 to 40. Because dry fly ash systems eliminate the need for an ash sluice water discharge, they represent a means of achieving zero discharge.

Vacuum Systems. In this type of system, fly ash is pneumatically conveyed to a dry storage silo by means of a mechanical vacuum producer. An example of a vacuum system for dry fly ash is shown in Figure VII-15. Fly ash is drawn from the bottom of the ash hopper through the dust valves and segregating valves to the primary and secondary collectors above the dry storage silo. The dust-free air from the collectors is sent through a cartridge filter before it is allowed to pass through the mechanical blowers where it is vented to the atmosphere.

Vacuum systems are limited in conveying distance. The distance to which material can be conveyed depends on the configuration of the system and plant altitude above sea level. The application of vacuum systems is generally limited from 500 to 700 feet of distance from the ash hoppers to the dry storage silos (39). The simplicity of vacuum systems makes them particularly advantageous in systems with 35 to 40 ESP hoppers.

Equipment. The following list of equipment comprises the major components of a vacuum system:

1. vacuum producers--mechanical or hydraulic;

2. valves--type "E" Dust Valves and segregating valves;

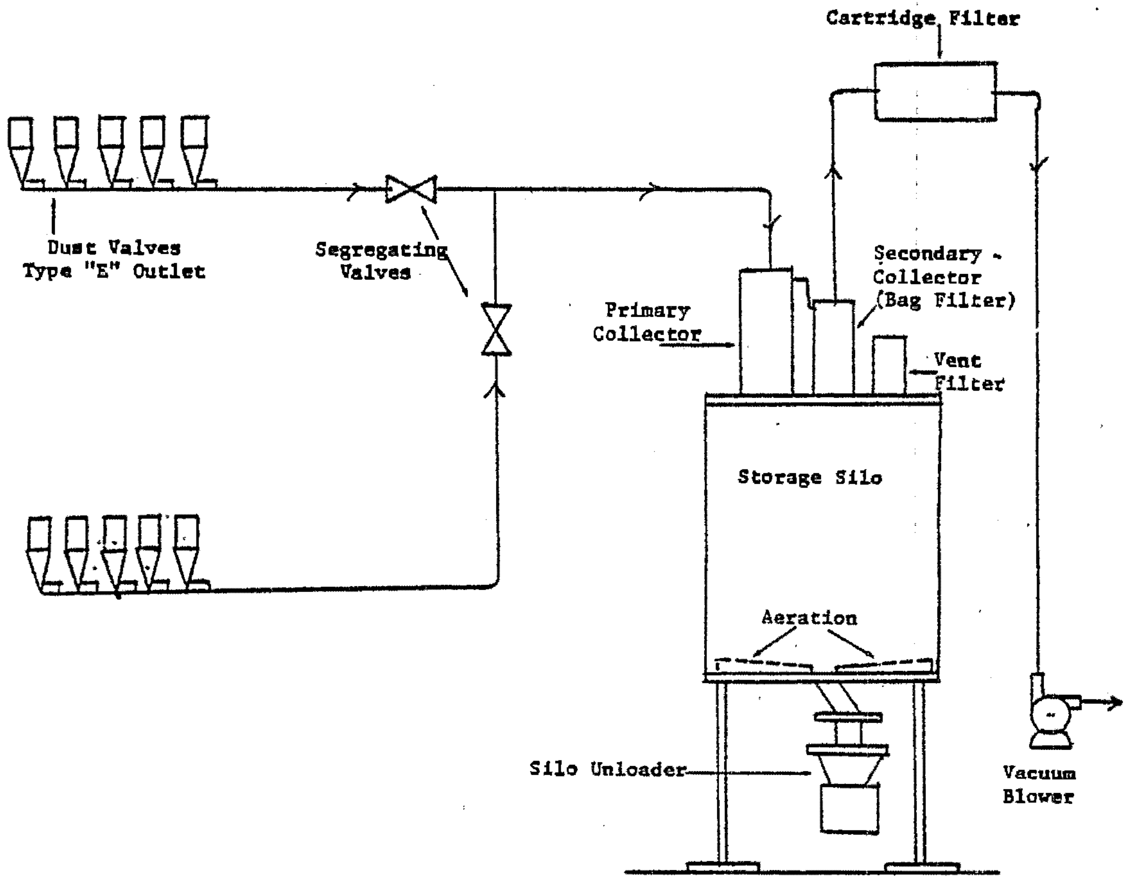
Cartridge Filter
Dust Valves
Type "E" Outlet
Segregating Valves
Secondary Collector (Bag Filter)
Primary Collector
Vent Filter
Storage Silo
Aeration
Silo Unloader
Vacuum Blower

Figure VII-15
DRY FLY ASH HANDLING - VACUUM SYSTEM

3. conveying pipe;
4. dry storage--silo, dust collectors, and vent filters;
5. dust conditioners (or unloaders); and
6. controls.

Many vacuum systems use mechanical exhausters to provide the necessary vacuum to convey fly ash to the dust collectors. These mechanical exhausters are 300- to 400-hp blowers (39), which are similar to those used in pressure systems. Vacuum production may also be provided by mechanical vacuum pumps motor driven machines of either the dry or water-injected positive displacement type or the water sealed rotary bucket type. Experience has shown that water-injected lobe type positive displacement vacuum producers cannot be used in cases where flue gases are high in sulfur dioxide (40). In such cases, dry vacuum pumps or watersealed machines must be used to avoid corrosion. The use of any mechanical vacuum pump requires the installation of collecting equipment of the highest possible efficiency ahead of the pump.

Figure VII-16 presents a diagram of a hydraulic vacuum producer. This particular unit, marketed under the trade name "Hydrovactor," is manufactured by the Allen-Sherman-Hoff Company. The hydrovactor makes use of high-pressure water (from 100 to 300 psi) discharged through an annular ring of nozzles into a venturi throat to create the vacuum to convey dust to the collectors (40). A similar unit, known as a "Hydroveyor," is manufactured by United Conveyor Corporation. The amount of water required, the pressure of the water, and the extent of the vacuum produced are a function of the ash generating rate and distance to the storage silo. Typical values might be 1,500 gpm of water through the venturi to draw 100 pounds per minute of air at 13 inches of mercury (39).

Figure VII-17 illustrates the type "E" dust valve which is installed under the fly ash collection hoppers. This valve is air-electric operated and is designed to admit ambient air through integrally mounted inlet check valves. As the slide gate is opened, air drawn through these valves and from the interstices in the dust becomes the conveying medium which transports the fly ash. Valve opening and closing is controlled by fluctuations in the vacuum at the producer. A drop in vacuum indicates an empty hopper, so that an operator, or an automatic control device, is alerted to move to the next point of dust collection.

When the fly ash is conveyed from two or more branch lines, segregating values are used to block off any branched lines which are not in use. By isolating the lines in this manner, the full energy of the conveying air can be applied to one branch at a time without the possibility of loss of conveying capacity due to leaks in other branches. Segregating valves may be provided with chain wheel or hand

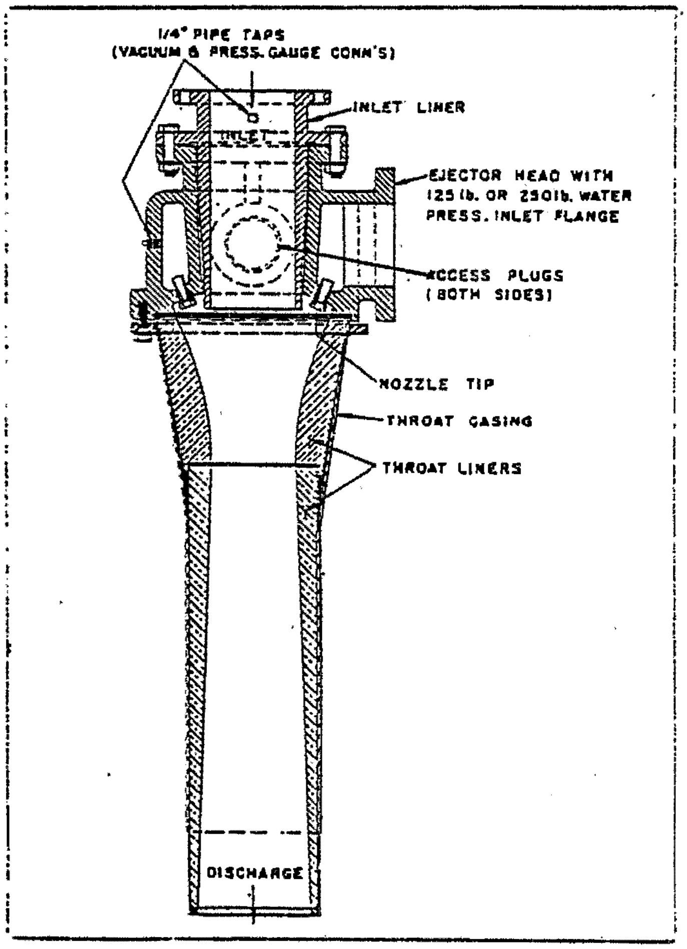
1/4" PIPE TAPS
(VACUUM & PRESS. GAUGE CONN'S)
INLET
INLET LINER
EJECTOR HEAD WITH
125 lb. OR 250lb. WATER
PRESS. INLET FLANGE
ACCESS PLUGS
(BOTH SIDES)
NOZZLE TIP
THROAT CASING
THROAT LINERS
DISCHARGE

Figure VII-16

DIAGRAM OF A HYDRAULIC VACUUM PRODUCER

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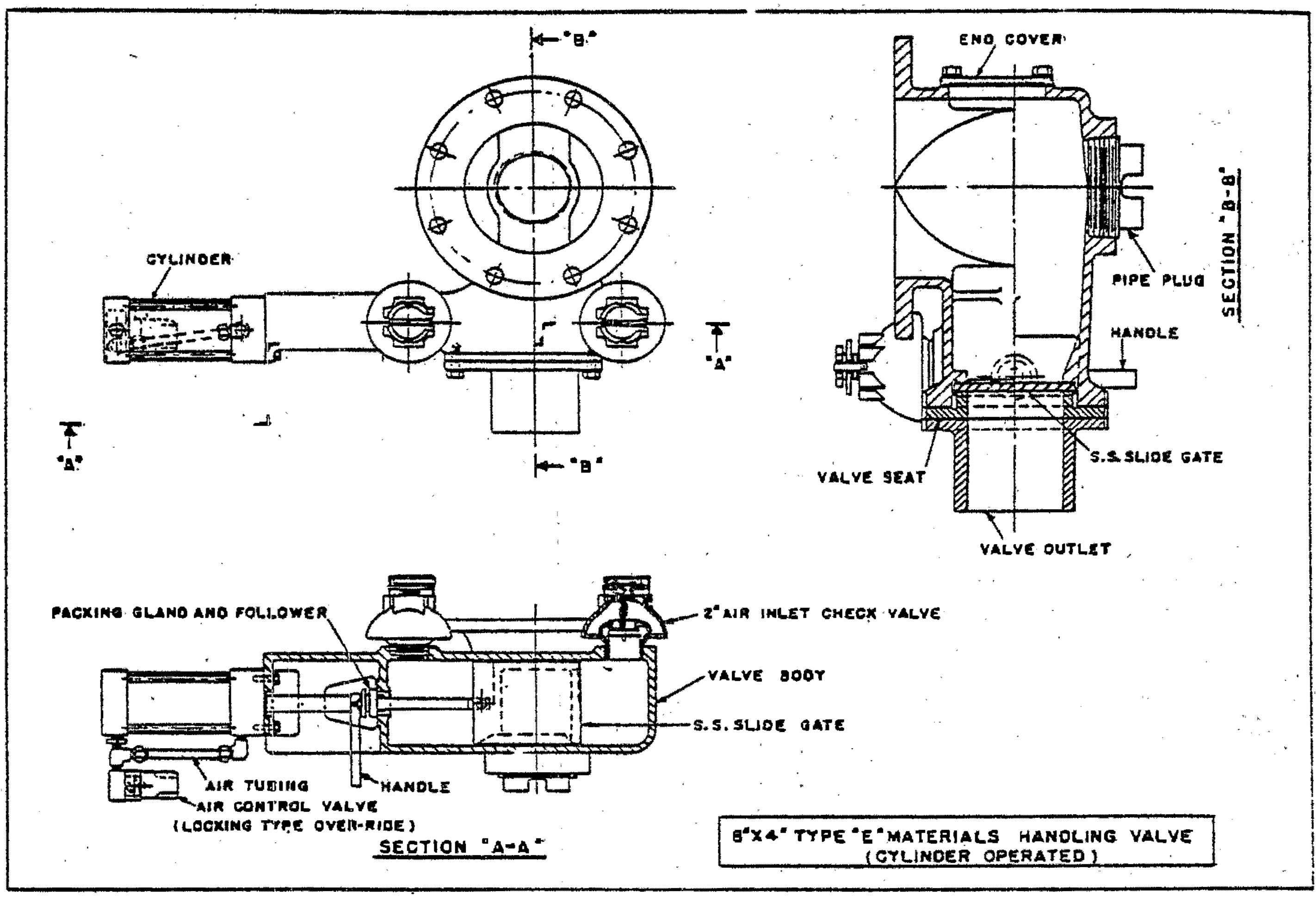
"B"
END COVER
CYLINDER
PIPE PLUG
SECTION "B-B"
HANDLE
"A"
"A"
"B"
S.S. SLIDE GATE
VALVE SEAT
VALVE OUTLET
PACKING GLAND AND FOLLOWER
2" AIR INLET CHECK VALVE
VALVE BODY
S.S. SLIDE GATE
AIR TUBING
HANDLE
AIR CONTROL VALVE
(LOCKING TYPE OVER-RIDE)
SECTION "A-A"
8"X4" TYPE "E" MATERIALS HANDLING VALVE
(CYLINDER OPERATED)

Figure VII-17

TYPE "E" DUST VALVES

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wheel operators as well as air-electric operators as shown in figure VII-18.

There are three types of pipe generally used in ash handling:

1. carbon steel pipe,

2. centrifugally cast iron pipe, and

3. basalt-lined pipe.

In general, the carbon steel and centrifugally cast iron pipes are most commonly used for dry handling (39). Basic pipe for ash handling service have a Brinnell Hardness Number (BHN) of 280; fittings are harder (approximately 400 BHN) to combat the added abrasive action at bends in a conveying line (40). Typical pipe and fittings are shown in figure VII-19. Integral wear back, tangent end fittings are used. A line of fittings with replaceable wear backs is available for vacuum systems. These wear backs are reversible so that each provides two points of impact where abrasion is most severe. In addition, each wear back, for a given size pipe fitting, can be used on all fittings of that size. Some typical line sizes which may be used for varying system capacities are provided in table VII-13. Experience has shown that one line should handle no more than 50 TPH fly ash and that two lines with cross-over provision should be run to the silo (40).

Dust caught by the collectors is continuously dropped into fly ash storage silo where it is held until disposed. Storage silos may be of carbon steel or hollow concrete stave construction. Flat bottom silos are equipped with aeration stones or slides to fluidize dust and induce flow to the discharge outlets. Motor driven blowers supply the fluidizing air. Silos are also provided with bag vent filters to prevent the discharge of dust along with displaced air as the silo is being filled. Alternately, venting can be provided by a duct from the silo roof back to the precipitator inlet. It may be necessary to supply lowpressure blowers on the vent duct to overcome losses which may prevent release of the conveying air, resulting in a pressure build up in the silo and drop-out of the fly ash in the duct.

Fly ash is normally deposited in trucks or railroad cars for transport to a dump area. In such cases, it is necessary to wet the dust to prevent it from blowing off conveyances during transportation. This is accomplished by means of conditioners which may be of the horizontal rotary pug-mill type or the vertical type.

The horizontal type is suitable for conditioning a maximum of 180 tons of dust per hour with water additions as high as 20 percent by weight (40). This unit requires a rotary feeding device between the discharge point and the unloader inlet to feed dry ash at a steady measured rate. Dust is fed by means of the star (rotary) feeder to the inlet of a screw feeder which carries the dust to the end of a rotating drum. Water is added at the discharge point of the screw feeder and at various points along the drum as the dust is tumbled and

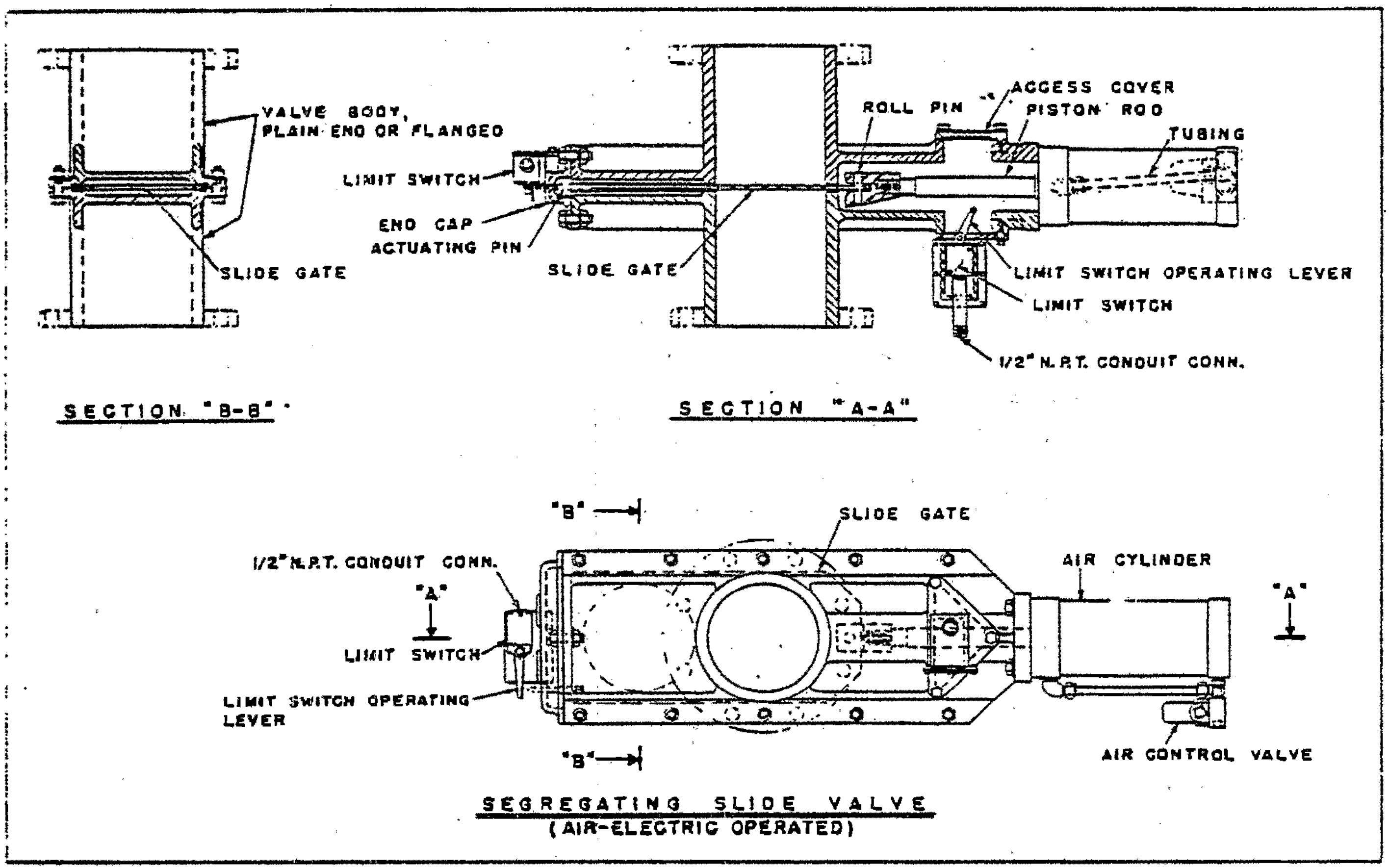
VALVE BODY, PLAIN END OR FLANGED
SLIDE GATE
SECTION "B-B"
LIMIT SWITCH
END CAP
ACTUATING PIN
SLIDE GATE
ROLL PIN
ACCESS COVER
PISTON ROD
TUBING
LIMIT SWITCH OPERATING LEVER
LIMIT SWITCH
1/2" N.P.T. CONDUIT CONN.
SECTION "A-A"
"B"
SLIDE GATE
1/2" N.P.T. CONDUIT CONN.
"A"
LIMIT SWITCH
LIMIT SWITCH OPERATING LEVER
AIR CYLINDER
"A"
AIR CONTROL VALVE
"B"
SEGREGATING SLIDE VALVE
(AIR-ELECTRIC OPERATED)

Figure VII-18

SEGREGATING VALVES

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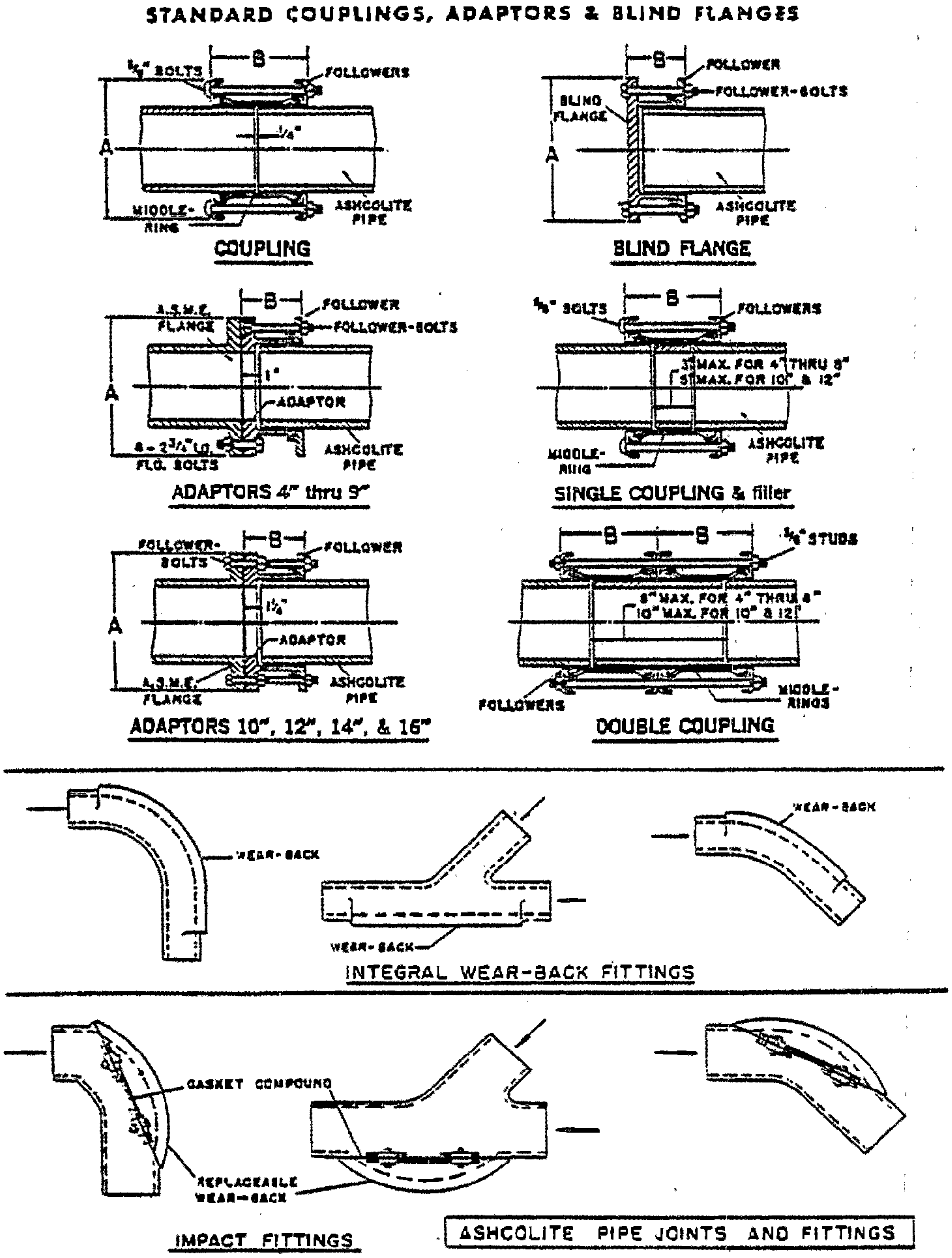
STANDARD COUPLINGS, ADAPTORS & BLIND FLANGES
B
5/8" BOLTS
FOLLOWERS
1/4"
A
MIDDLE-RING
ASHCOLITE PIPE
COUPLING
FOLLOWER
FOLLOWER-BOLTS
BLIND FLANGE
ASHCOLITE PIPE
BLIND FLANGE
A.S.M.E. FLANGE
FOLLOWER
FOLLOWER-BOLTS
1"
ADAPTOR
8 - 2 3/4" LG. FLG. BOLTS
ASHCOLITE PIPE
ADAPTORS 4" thru 9"
5/8" BOLTS
FOLLOWERS
3" MAX. FOR 4" THRU 8"
5" MAX. FOR 10" & 12"
MIDDLE-RING
ASHCOLITE PIPE
SINGLE COUPLING & filler
FOLLOWER-BOLTS
FOLLOWER
1 1/4"
ADAPTOR
A.S.M.E. FLANGE
ASHCOLITE PIPE
ADAPTORS 10", 12", 14", & 16"
5/8" STUDS
8" MAX. FOR 4" THRU 8"
10" MAX. FOR 10" & 12"
FOLLOWERS
MIDDLE-RINGS
DOUBLE COUPLING
WEAR-BACK
WEAR-BACK
WEAR-BACK
INTEGRAL WEAR-BACK FITTINGS
GASKET COMPOUND
REPLACEABLE WEAR-BACK
IMPACT FITTINGS
ASHCOLITE PIPE JOINTS AND FITTINGS

Figure VII-19

TYPICAL PIPES AND FITTINGS FOR ASH CONVEYING

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Table VII-13

ASH CONVEYING CAPACITIES OF VARIOUS SIZE PIPES (39)

Pipe Size (inside diameter in inches)	Ash Generating Rate (tons/hour)
6	15-20
8	25-50
10	50-75

rolled past a series of scrapers toward the discharge point. Operator attention is essential to the satisfactory functioning of this conditioner.

The vertical conditioner is more adaptable to automatic operation with 20 percent water addition (40). This unit is supplied with a fluidizing feeder and metering cut off gate to provide uniform feed. Dust enters a chamber on the top of the vertical conditioner where it falls onto a rotating distributing cone. This creates a cylindrical curtain of dust which is sprayed from numerous directions by high-velocity fog-jet nozzles. The wetted dust, which is driven onto the walls of the bottom chamber, is moved toward the bottom discharge nozzle by means of a pair of motor-driven scraper blades.

Both units require water at a minimum pressure of 80 psi to achieve intimate mixing. Water supplied at a lower pressure cannot penetrate the mass of dust passing through in a very short period of time (40).

Controls for vacuum fly ash systems are activated by changes in vacuum. When a hopper is emptied of fly ash, the system vacuum will drop. A pressure switch then activates a rotary step switch to close the dust valve under the hopper and to open the valve under the next hopper. This procedure continues until all the hoppers are empty.

Maintenance. There are several high-maintenance areas associated with vacuum systems:

1. Vacuum Blowers - Problems may arise if the conveying air is insufficiently filtered upstream of the blower. Dust in the conveying air would then pass through the blower, and erode the blades.

2. Bag Filter - Bag filter breakage is a common maintenance problem, creating a fugitive dust problem usually just within the confines of the silo area.

3. Leakage - Leaks in the couplings of the pipe system can reduces the conveying power of the system. Maintenance problems for leakage are much less severe for vacuum systems as compared to pressure system leakage because all leaks are inward.

4. Vacuum Silo - Since the silo is generally outside the plant area, maintenance may be less frequent. For the vacuum silo, this can be more of a problem because it is more complex than a pressure silo due to the need for collectors.

Pressure Systems. This system conveys fly ash from individually controlled air locks (at the bottom of the ESP hoppers) to a dry storage silo by means of pressure provided by positive displacement blowers. A schematic diagram of a pressure system appears in figure VII-20. The mechanical blowers supply compressed air at pressures of

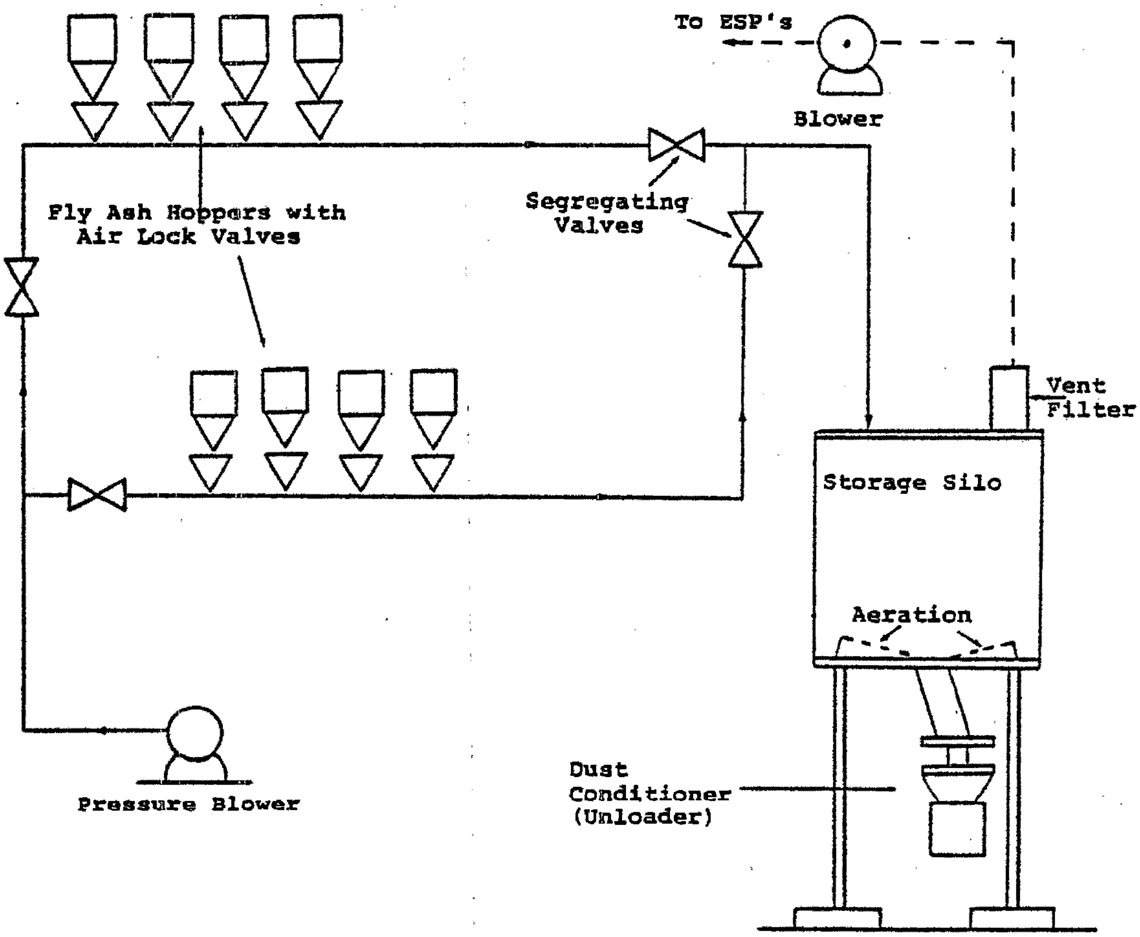

To ESP's
Blower
Fly Ash Hoppers with Air Lock Valves
Segregating Valves
Vent Filter
Storage Silo
Aeration
Dust Conditioner (Unloader)
Pressure Blower

Figure VII-20
DRY FLY ASH HANDLING SYSTEM - PRESSURE SYSTEM

up to 32 psi (40). The main difference between the vacuum and pressure systems is that the pressure system does not require cyclone collectors at the storage silo; instead, a vent filter relieves the silo of the air displaced by the incoming dust as well as the expanded volume of the conveying air. In some systems, a return line is run from the vent filter back to the ESP hopper to avoid possible fugitive dust emissions from the vent filter. A blower is usually required on this line to overcome draft losses.

Equipment. The major components of a pressure system are essentially the same as those of a vacuum system with the following exceptions.

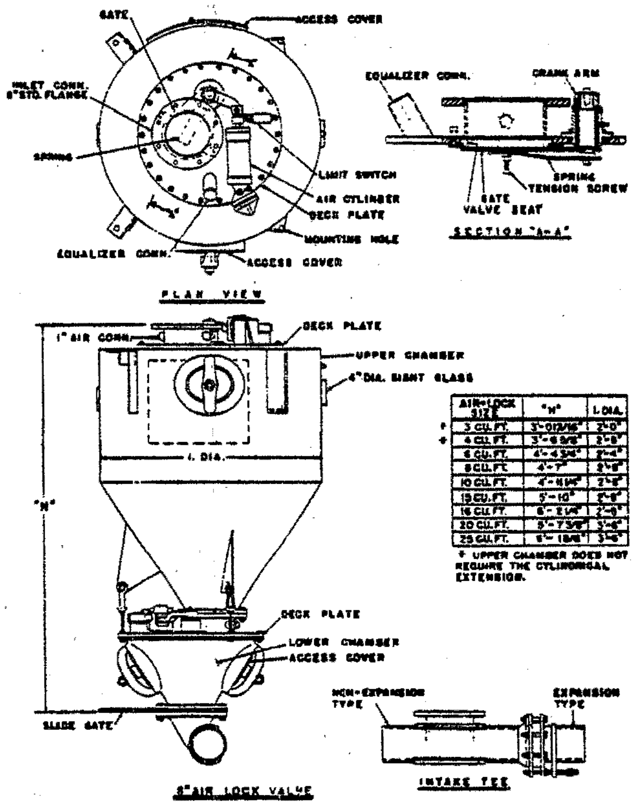
Air locks are used to transfer fly ash from a hopper at one pressure to a conveying line at a higher pressure (figure VII-21). These are available in a wide range of capacities to meet any handling rate required of a pressurized conveying system. Air- electric operated cylinders control the positioning of upper and lower feed gates in proper sequence with the equalizing valves between upper and lower chambers. Manual cut off gates are supplied at the inlet and discharge of each air lock to permit its removal without interrupting operation of the rest of the system (40).

Silo storage is the same as for vacuum systems except that dust collectors are not required; however, a self-cleaning vent bag filter is required. Air-to-cloth ratio should be no greater than 2.5 cubic feet per minute to 1 square foot of bag cloth area (40). Vent ducts provide an alternate means of relieving air from silos.

Controls for pressure systems operate on a timed basis determined by the amount of dust stored in each row of collector hoppers. Individual air locks on any given row are carefully interlocked with the other air locks to prevent discharge of more than one hopper at a time. Programmable controls are available to permit changing of air lock cycling where dust loading fluctuations are expected.

Maintenance. There are several areas of high maintenance in a pressure system. The blowers, in general, are high-maintenance items. However, the risk of erosion of fan blades due to dust in the conveying air is not as great in the pressure system as it is in the vacuum system. Leakage, on the other hand, represents a more severe problem in the pressure system than it does in the vacuum system. Leaks in the pipe couplings can cause greater fugitive dust problems because of the positive pressure in the lines. In this sense, the pressure system is not as "clean" as the vacuum system.

Fugitive Dust Emissions. Dry fly ash handling systems potentially have significant dust emission problems. These dust emissions can occur at various locations within the ash handling system. Fly ash is a very abrasive material so problems generally arise in maintenance. Positive pressure fly ash transport systems generally incur problems in the pipe joints. One of the major maintenance problem areas with vacuum systems is with the bag filters used in the secondary or tertiary collectors on top of the storage silo. If these bags break,


GATE
ACCESS COVER
INLET CONN.
8" STD. FLANGE
SPRING
LIMIT SWITCH
AIR CYLINDER
DECK PLATE
MOUNTING HOLE
EQUALIZER CONN.
ACCESS COVER
PLAN VIEW
EQUALIZER CONN.
CRANK ARM
SPRING
TENSION SCREW
GATE
VALVE SEAT
SECTION "A-A"
1" AIR CONN.
DECK PLATE
UPPER CHAMBER
4" DIA. SIGHT GLASS
L DIA.
"H"
DECK PLATE
LOWER CHAMBER
ACCESS COVER
SLIDE GATE
8" AIR LOCK VALVE
NON-EXPANSION TYPE
EXPANSION TYPE
INTAKE TEE

	AIR-LOCK SIZE	"H"	L DIA.
*	3 CU. FT.	3'-0 13/16"	2'-0"
*	4 CU. FT.	3'-6 3/8"	[illegible]
	6 CU. FT.	4'-4 3/4"	[illegible]
	8 CU. FT.	4'-7"	[illegible]
	10 CU. FT.	[illegible]	[illegible]
	15 CU. FT.	5'-10"	[illegible]
	16 CU. FT.	6'-2 1/4"	[illegible]
	20 CU. FT.	5'-7 3/8"	[illegible]
	25 CU. FT.	[illegible]	3'-6"

* UPPER CHAMBER DOES NOT REQUIRE THE CYLINDRICAL EXTENSION.

Figure VII-21

TYPICAL AIR LOCK VALVE FOR PRESSURE FLY ASH CONVEYING SYSTEM

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the dust-laden air stream will continue through the vacuum producer and into the atmosphere. If the vacuum producer is hydraulic, then the fly ash will be slurried with high-pressure water, eliminating the dusting problem. Dusting problems also arise from bag breakage if a mechanical exhauster is used. Another problem area is the unloader at the bottom of the silo where spray nozzles are used to wet the fly ash before it is dumped into the truck. These spray nozzles need continuous maintenance to avoid pluggage and subsequent dusting problems. Even with proper maintenance of the nozzles, the area around the unloader is still exposed to excessive dusting. Some facilities use roll-up doors to close off this area and vent the air back to the precipitator.

EPA conducted a telephone survey to determine the types of regulations on fugitive dust emissions which exist among different federal, state, and local authorities. In general, there are no regulations which apply specifically to dry fly ash handling systems. Fugitive dust emissions are usually covered by a more general regulation regarding particulate emissions such as a general opacity reading at the plant boundary. Regular monitoring or inspection for dust emissions is generally not required. Enforcement is based primarily on complaints.

Retrofitting. The motivation for retrofitting dry fly ash handling systems may stem from a variety of circumstances:

1. A shortage of water may exist for sluicing the fly ash to ponds,

2. State or local regulations for certain aqueous discharges may result in a retrofit, and

3. A marketable use for the fly ash such as an additive for making cement.

Very little, if any, equipment could be reused in retrofitting to a dry fly ash system from a wet handling system. The equipment needing removal would be:

- Valves allowing flow from the ESP hopper into the sluice line, if the sluice line runs into the hopper;

- Pumps for carrying fly ash to the pond; and

- The line used for conveying the ash slurry.

In some cases, fly ash is pneumatically conveyed via a hydrovactor (or hydroveyor) to a mixing tank where it mixes with bottom ash for sluicing to a pond. The piping and vacuum producers, in these cases are potentially reusable. It would be necessary to shut down the existing equipment during installation of the new equipment.

Trip Reports. EPA visited several plants in order to define various bottom ash and fly ash handling practices. This subsection discusses dry fly ash handling systems encountered at some of these plants.

Plant 1811. This plant is a 615-MW coal-fired electric power generating station located in Northern Indiana. The ash is generated by two cyclone type boilers of 194 and 422 MW each. The coal is characterized as low sulfur with an ash content of 10 to 12 percent with 11 percent as the average. This bituminous coal comes from Bureau of Mines Coal Districts 10 and 11.

The fly ash handling system currently in use at the plant is a dry vacuum system that was retrofitted in early 1979. The previous system was a wet sluicing operation that used a hydroveyor and ponding. The major equipment for this dry system is presented schematically in figure VII-22. This is a dual system in terms of the separators, i.e., cyclones and bagfilters, and the mechanical exhausters. There are separate lines which run from Unit 8 ESP hoppers and Unit 7 ESP hoppers. These lines feed separate cyclone collectors and bagfilters, but one silo is used to store the ash transported by the two lines. The storage silo has a diameter of 35 feet. Sixteen hoppers feed the Unit 8 line (10-inch diameter pipe) and eight feed Unit 7 line. The distance from the hoppers to the silo is approximately 300 feet. No major problems occurred in the changeover from hydroveying the ash to ponds to vacuum handling of the ash to a storage silo.

The fly ash system was fairly new at the time of the site visit, and no major operating difficulties had been encountered. Early experience showed that the optimum operating procedure was to run the mechanical exhausters continuously; intermittent operation had caused some difficulty in achieving a sufficient vacuum for fly ash transport. Minor erosion of the exhausters had occurred.

In 1978, the plant generated 38,100 tons of fly ash. This ash is currently trucked to a landfill site for disposal by an outside firm. Closed cement trucks are used; the ash is not conditioned at the silo.

Plant 1164. This plant is a 447-MW coal-fired powerplant located in Northwestern Colorado. The plant consists of two units: Unit 1 completed in 1965 and Unit 2 in 1976. The facility is a baseload plant which uses cooling towers for condenser heat dissipation, dry fly ash transport, and a zero discharge bottom ash sluicing system. The plant burns a bituminous coal from Bureau of Mines Coal District 17. The plant is sufficiently close to the coal mine (9 miles) to be considered a mine-mouth operation. Plant water is drawn from a nearby river. The facility uses a vapor compression distillation unit to recover recycleable water from cooling water blowdown. All wastewaters are ultimately handled by an evaporation pond. A generalized flow scheme for the plant appears in figure VII-23. The water system, as currently in operation, was designed by Stearns-Rodgers.

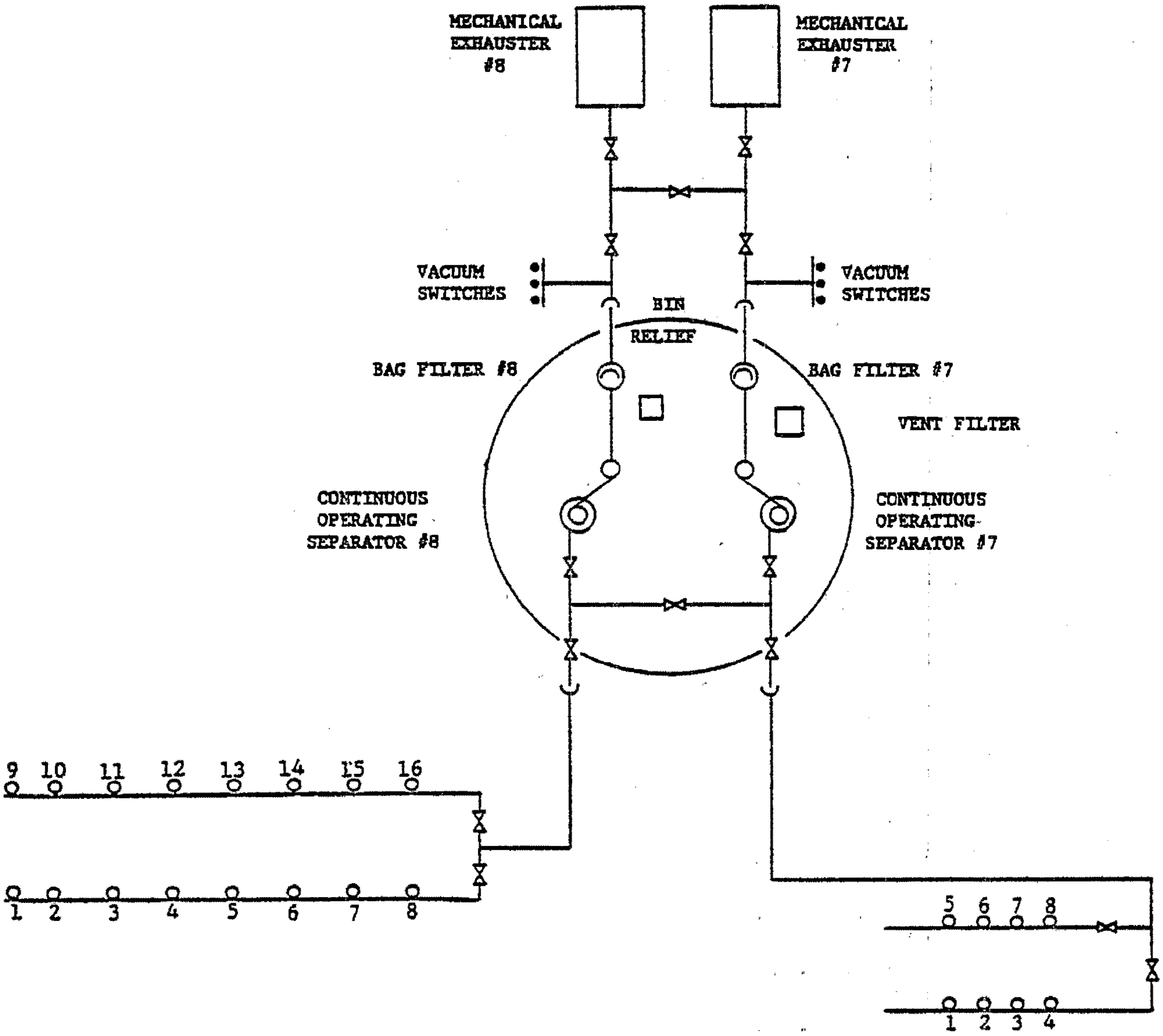
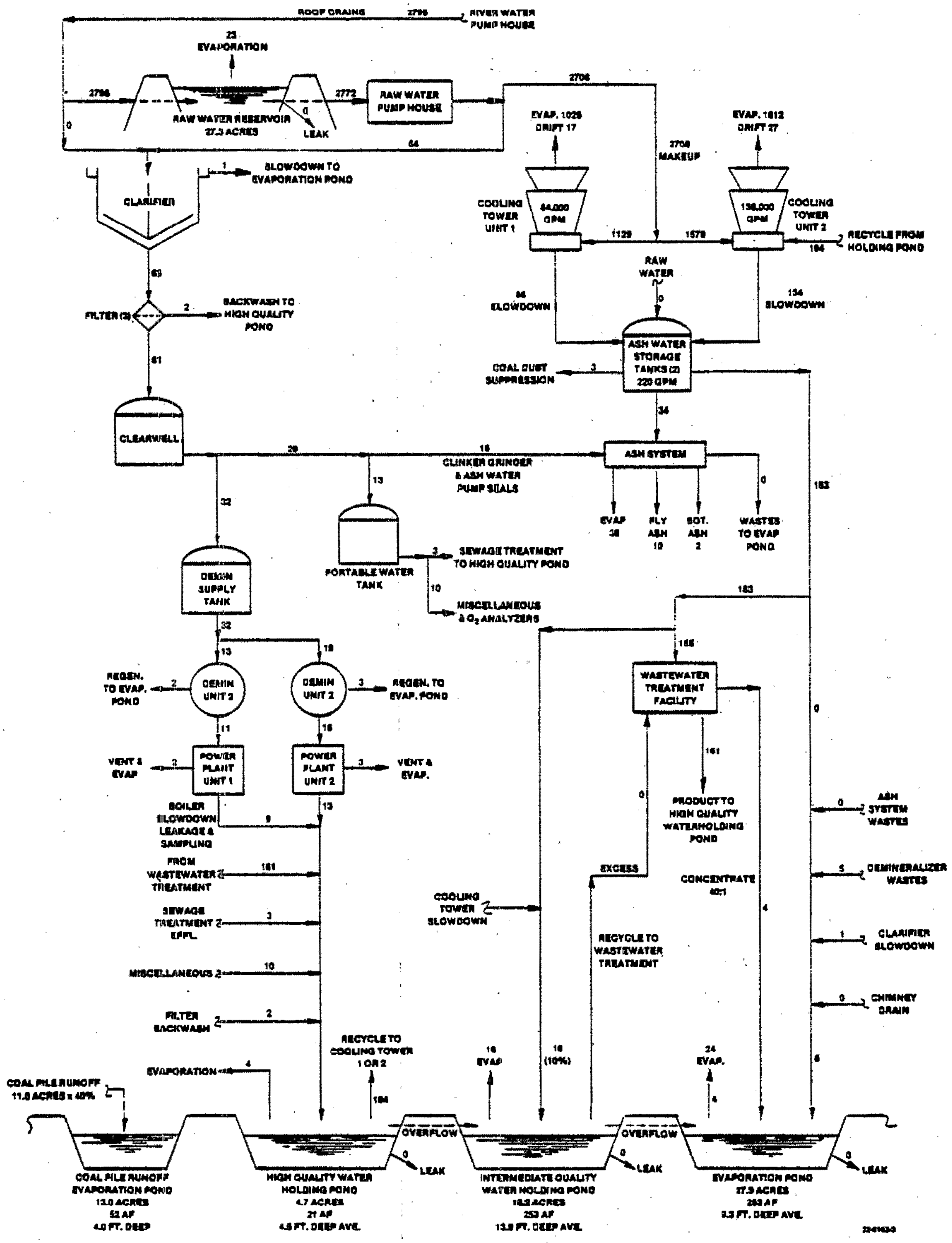

MECHANICAL EXHAUSTER #8
MECHANICAL EXHAUSTER #7
VACUUM SWITCHES
VACUUM SWITCHES
BIN RELIEF
BAG FILTER #8
BAG FILTER #7
VENT FILTER
CONTINUOUS OPERATING SEPARATOR #8
CONTINUOUS OPERATING SEPARATOR #7
9 10 11 12 13 14 15 16
1 2 3 4 5 6 7 8
5 6 7 8
1 2 3 4

Figure VII-22
FLY ASH SILO AND HOPPERS/PLANT 1811


ROOF DRAINS
2796
RIVER WATER PUMP HOUSE
23 EVAPORATION
2796
RAW WATER RESERVOIR 27.3 ACRES
0 LEAK
2772
RAW WATER PUMP HOUSE
2706
0
64
EVAP. 1028 DRIFT 17
EVAP. 1612 DRIFT 27
2706 MAKEUP
1 BLOWDOWN TO EVAPORATION POND
CLARIFIER
COOLING TOWER UNIT 1
84,000 GPM
136,000 GPM
COOLING TOWER UNIT 2
1129
1579
RECYCLE FROM HOLDING POND
184
RAW WATER
0
63
FILTER (3)
2 BACKWASH TO HIGH QUALITY POND
98 BLOWDOWN
154 BLOWDOWN
61
ASH WATER STORAGE TANKS (2) 220 GPM
COAL DUST SUPPRESSION
3
CLEARWELL
34
29
16 CLINKER GRINDER & ASH WATER PUMP SEALS
ASH SYSTEM
13
32
EVAP 38
FLY ASH 10
BOT. ASH 2
0 WASTES TO EVAP POND
183
PORTABLE WATER TANK
3 SEWAGE TREATMENT TO HIGH QUALITY POND
10 MISCELLANEOUS & O_2 ANALYZERS
DEMIN SUPPLY TANK
183
32
13
19
166
REGEN. TO EVAP. POND
2
DEMIN UNIT 2
DEMIN UNIT 2
3 REGEN. TO EVAP. POND
WASTEWATER TREATMENT FACILITY
11
16
0
VENT & EVAP
2
POWER PLANT UNIT 1
POWER PLANT UNIT 2
3 VENT & EVAP.
161
BOILER BLOWDOWN LEAKAGE & SAMPLING
9
13
0
PRODUCT TO HIGH QUALITY WATERHOLDING POND
0 ASH SYSTEM WASTES
FROM WASTEWATER TREATMENT
161
EXCESS
CONCENTRATE 40:1
5 DEMINERALIZER WASTES
COOLING TOWER SLOWDOWN
4
SEWAGE TREATMENT EFFL.
3
RECYCLE TO WASTEWATER TREATMENT
1 CLARIFIER BLOWDOWN
MISCELLANEOUS
10
0 CHIMNEY DRAIN
FILTER BACKWASH
2
RECYCLE TO COOLING TOWER 1 OR 2
16 EVAP
16 (10%)
24 EVAP.
6
EVAPORATION
4
COAL PILE RUNOFF 11.0 ACRES x 40%
184
4
OVERFLOW
OVERFLOW
0 LEAK
0 LEAK
0 LEAK
COAL PILE RUNOFF EVAPORATION POND 13.0 ACRES 52 AF 4.0 FT. DEEP
HIGH QUALITY WATER HOLDING POND 4.7 ACRES 21 AF 4.5 FT. DEEP AVE.
INTERMEDIATE QUALITY WATER HOLDING POND 18.2 ACRES 253 AF 13.9 FT. DEEP AVE.
EVAPORATION POND 27.3 ACRES 253 AF 9.3 FT. DEEP AVE.

CONDITIONS:
ALL FLOWS IN AVERAGE GPM
70% CAPICITY FACTOR
AVERAGE ANNUAL COOLING TOWER EVAPORATION
COOLING TOWER CONCENTRATION 11 CYCLES
COOLING TOWER DRIFT 0.02% OF CIRC. WATER FLOW
RESERVOIR & POND NET ANNUAL AVERAGE
EVAPORATION 0.86 GPM/ACRES (18.7 IN/YR)

Figure VII-23

FLOW DIAGRAM FOR PLANT 0822

The dry fly ash handling system for the plant removes fly ash from the boiler economizer hoppers and precipitator hoppers on Units 1 and 2 and transports the ash to a common fly ash silo where the ash is loaded into trucks. The trucks then transport the ash back to the mine site for burial. The system is pressurized and uses air as the conveying media. Ash conveying blowers supply the conveying air. Fly ash is fed into the system from the economizer and precipitator hoppers by "nuva" feeders in a programmed sequence and the air flow carries the ash to the plant fly ash silo. Exhaust air from the silo is vented by the fly ash silo vent fans to the Unit 2 precipitator flue gas inlet manifold.

Three positive displacement blowers are used to drive the fly ash from the ESP and economizer hoppers to the plant storage silo. These blowers include one spare. Blower 1 serves Unit 1; blower 3 serves Unit 2; and blower 2 is the spare. These blowers each have a capacity of 2,900 ACFM at 13.5 psig and are driven by 250 hp, 480-volt, 3-phase, 60-hertz, 1,800-rpm electric motors. A 10-inch line is run from the Unit 2 blower to the Unit 2 precipitator and economizer hoppers. Each of the two precipitators contain 16 ash hoppers and the economizer contains four hoppers. The conveying air is piped to service nine groups of hoppers, each group containing four hoppers. Fly ash from each group of four hoppers is automatically fed by "nuva" feeders in a programmed sequence contained in the fly ash control system which empties the hoppers in each group one at a time.

The fly ash system for Unit 1 consists of one four-branched conveyor, which automatically conveys fly ash from 24 precipitator "nuva" feeders. The "nuva" feeders are essentially airlocks which utilize fluidizing stones to achieve better dust flow characteristics from the hopper to the pressure pneumatic conveyor. "Nuva" is a trade name used by United Conveyor for their airlocks. The air displaced by ash in the precipitator feeders is vented through a bag filter to the atmosphere. Air displaced by the economizer ash is vented back into the hopper.

From the hoppers the fly ash and conveying air travel through a 10-inch line into the plant fly ash silo. The conveying air is vented from the silo through a 16-inch line by three fly ash silo vent fans. The air is piped through one of two 14-inch lines leading to the Unit 1 and 2 precipitators. The three silo vent fans are driven by 50-hp, 480-volt, 3-phase, 60-hertz, 1,800-rpm electric motors. The rotary unloaders condition the fly ash which is then hauled to the mine for disposal. Ash water from the bottom ash surge tank is pumped to the fly ash silo by two fly ash unloader pumps through a 6-inch line.

The most significant maintenance item is the blowers. These have required two mechanics full time due to the erosion of the compressors. Other problems occur with pipe fitting leakage due to pipe expansion. The pipe expands because of the high temperature (700 F) fly ash which is being conveyed.

This system was installed along with the bottom ash system in 1974 as a retrofit to Unit 1 and as new to Unit 2. No particular problems were encountered in this retrofit. Some downtime was required to hookup the fly ash conveying pipe and airlocks to the ESP and economizer hoppers. Also, the old wet sluicing pipe needed to be taken out. No pipe was reusable for the fly ash system.

Plant 3203. This plant is a 340-MW western bituminous coal- burning facility which fires a moderately low-sulfur coal (average 0.6 percent) with an average ash content of 12 percent. The availability of the three boilers has historically averaged 86 percent annually.

The dry fly ash handling system currently in use is a pressure system designed and installed by United Conveyor Corporation. Fly ash is generated by three pulverized dry bottom coal-fired units. Operating conditions at the plant indicate that 80 percent of the coal ash leaves the boilers via the flue gas stream. This corresponds to approximately 385 TPD of fly ash being generated. Approximately 0.3 percent of this fly ash is collected in the economizer hopper; the ash collected there is sluiced to the bottom ash handling system at a rate of 1 TPD. The majority of the remainder of the fly ash is collected in mechanical collecting devices, cyclones, with an efficiency of 75 percent. The remaining 25 percent is collected in the air preheater and stack hoppers. The fly ash collected is then conveyed under pressure to a storage silo for commercial use or disposal. Approximately 250 TPD of the fly ash is sold dry, or unconditioned, to a cement company as an additive for $1 per ton. The remainder is conditioned and trucked to an on site landfill.

The pressure system is diagrammed in figure VII-24. There are six hoppers per mechanical collector which feed through an airlock device into a pressurized (8-10 psig) pneumatic conveying line which leads to the storage silo. The distance from the cyclone hoppers to the storage silo is approximately 500 feet. The volume of the silo is 30,000 cubic feet and the pneumatic lines leading to the silo are 6 to 7 inches in diameter. This silo volume provides approximately a 2-day storage capacity and therefore requires dumping several times a week.

The equipment which required the most maintenance during the past 4 years of operation of the unit were (1) the blowers and (2) valves and elbows. There were no real problems with the rest of the system.

The motivation for retrofitting this system was twofold: a general water shortage problem existed and approximately 250 TPD of the fly ash was a saleable product at a rate of $1 per ton. At the time the pressure dry fly ash system was installed in 1975, a dewatering bin system and a third unit boiler were also installed. A 2-week outage for Units 1 and 2 was incurred when these retrofit systems were installed.

Utilization of the Systems. Data from the 308 survey were used to evaluate the distribution of fly ash handling systems for the following parameters:

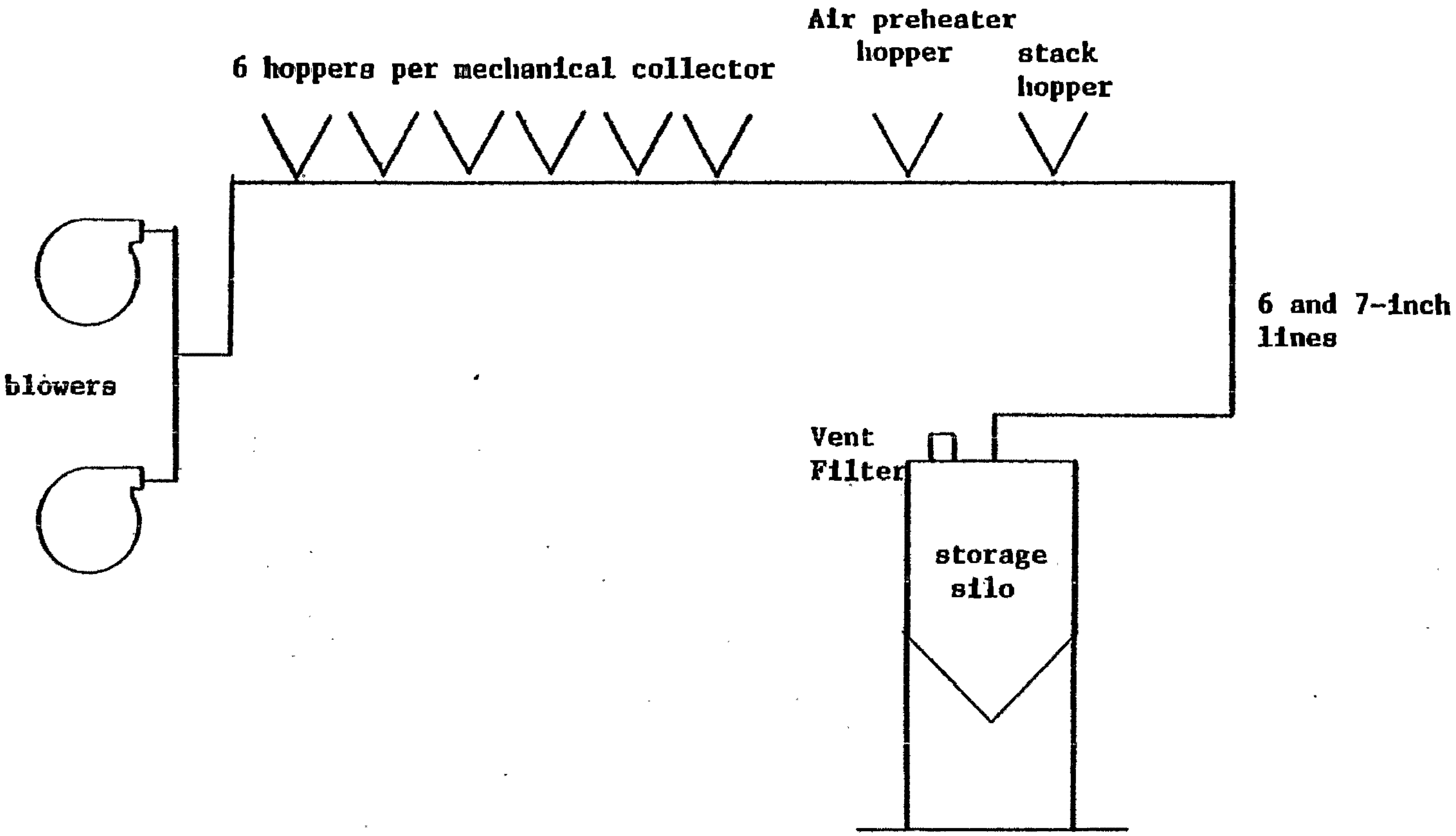

6 hoppers per mechanical collector
Air preheater hopper
stack hopper
blowers
6 and 7-inch lines
Vent Filter
storage silo

Figure VII-24
PRESSURE FLY ASH HANDLING SYSTEM FOR PLANT 3203

- fuel type,
- boiler type,
- location,
- size, and
- intake water quality.

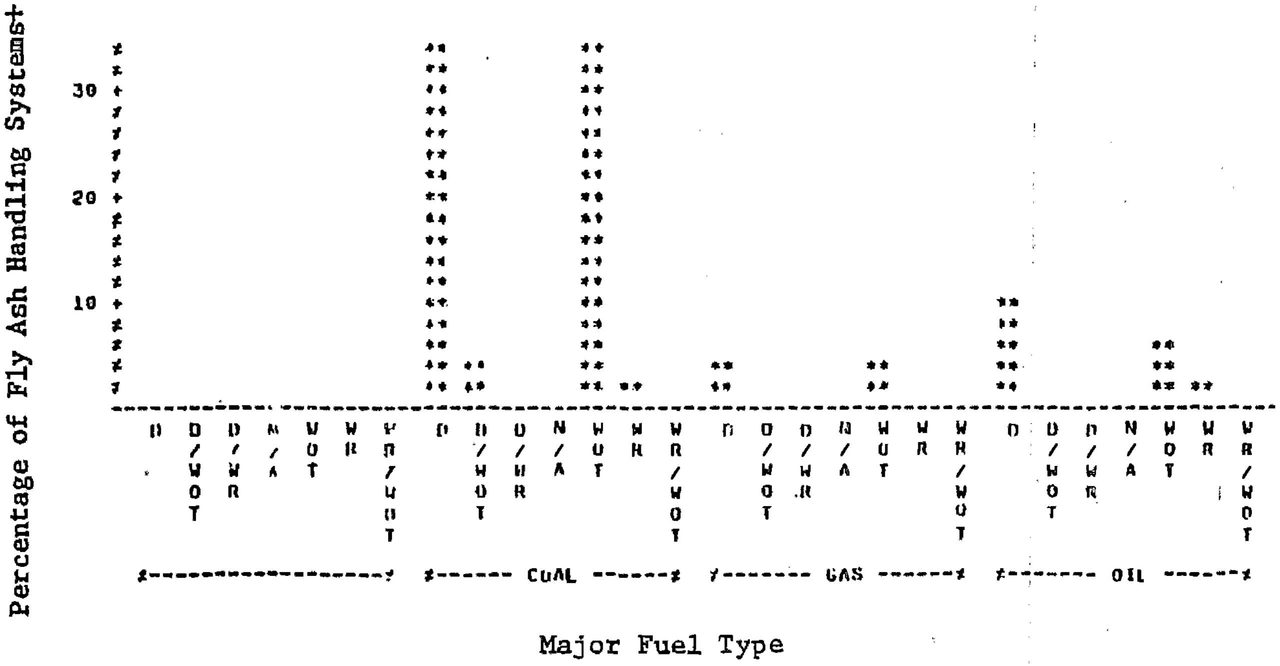
Fuel Type. The most important fuel type is coal. This fuel type accounts for 74 percent of the fly ash handling systems as shown in figure VII-25. Dry fly ash handling systems are as common as wet once-through systems for coal-burning facilities and represent 34 percent of all ash handling systems. Wet recirculating systems, however, are much less common, representing only 2 percent of all ash handling systems. This distribution does not change significantly among coal, gas, and oil-burning facilities. Thus, it seems that fuel type has little effect on the type of ash handling system used.

The distribution of ash handling systems among different coal types is shown in figure VII-26. Coal type does not seem to significantly affect the distribution of systems. Bituminous coal facilities, by far the most common of the three coal types considered, are split between dry and wet once-through systems. Wet recirculating systems are rare.

Boiler Type. Three major boiler types are considered in this analysis: cyclone, pulverized coal, and spreader stoker units. Figure VII-27 indicates that the type of boiler does influence the distribution of fly ash handling systems. Dry fly ash units are outnumbered three-to-one by wet once-through systems for cyclone units. Eighty to 90 percent of the ash produced by a cyclone boiler is bottom ash. Since the cyclone boiler is a slagging boiler, the bottom ash is usually handled wet; thus, it is not surprising that the remaining 10 to 20 percent of the ash is more frequently handled wet. Wet recirculating systems are rare (less than 2 percent of the systems reported) for cyclone boilers, as well as for pulverized and stoker boilers. Pulverized coal units seem to have the same distribution of fly ash handling systems as discussed previously for fuel types. Dry systems are very common (almost equal in number to wet once- through systems), and wet recirculating systems are rare. Spreader stoker units use a much larger proportion of dry systems than wet once-through systems. Wet recirculating systems are rare.

Location. The distribution of fly ash handling systems for each of the 10 EPA regions is shown in figure VII-28. A map displaying the EPA regions is provided in figure VII-29. The distribution indicates that there are some regional variances in the distribution of fly ash handling systems.

Regions I through III show a slightly greater frequency of dry systems (as opposed to wet once-through) and very few instances of wet

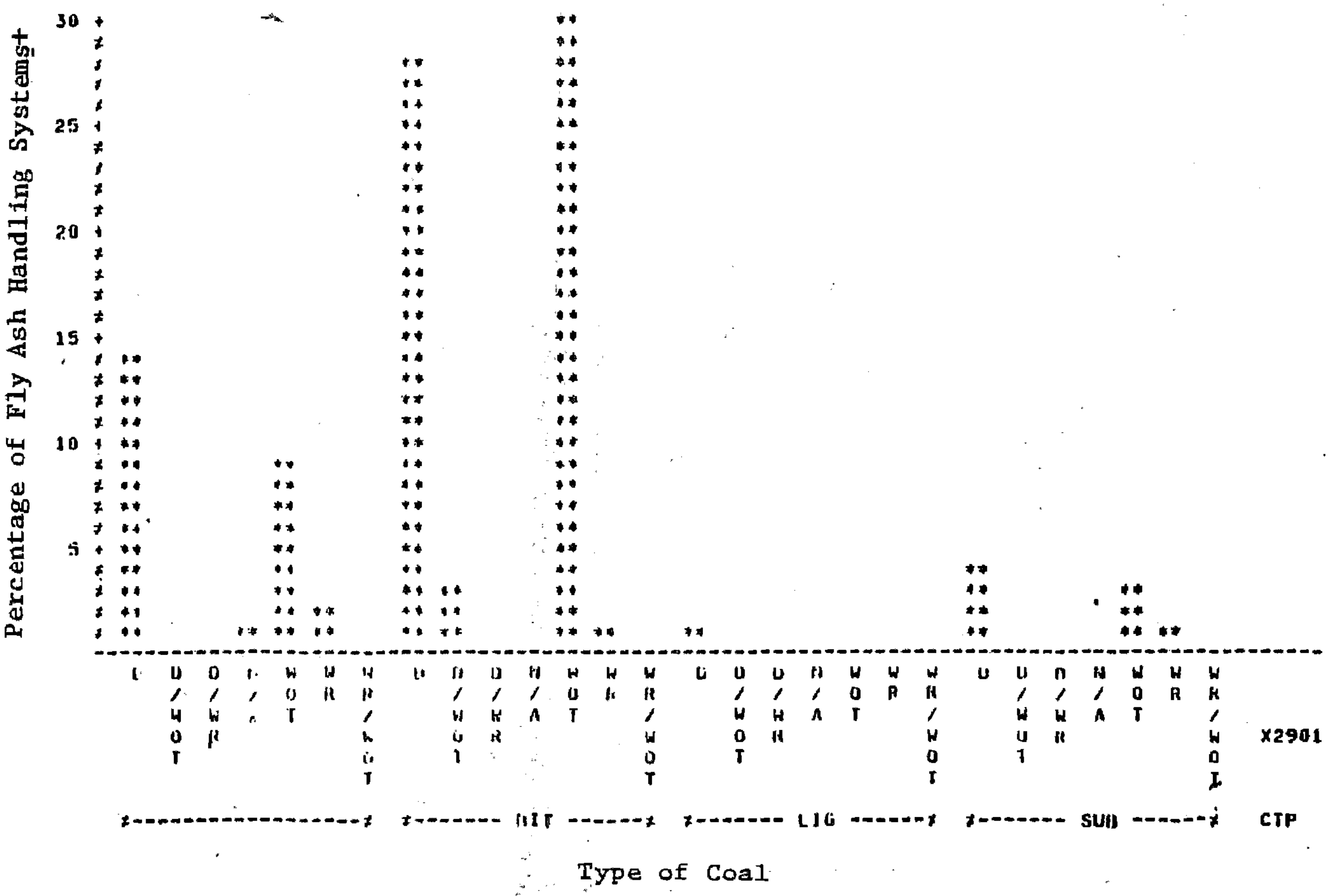


Key: D: Dry Fly Ash Handling System
WOT: Wet Once-Through Fly Ash Handling System
WR: Wet Recirculating Fly Ash Handling System

NOTE: Plants which could not be identified under a subgroup appear in a subgroup on the far left of the chart, designated by a "." or by "---".

Figure VII-25

DISTRIBUTION OF FLY ASH HANDLING SYSTEMS BY MAJOR FUEL TYPES

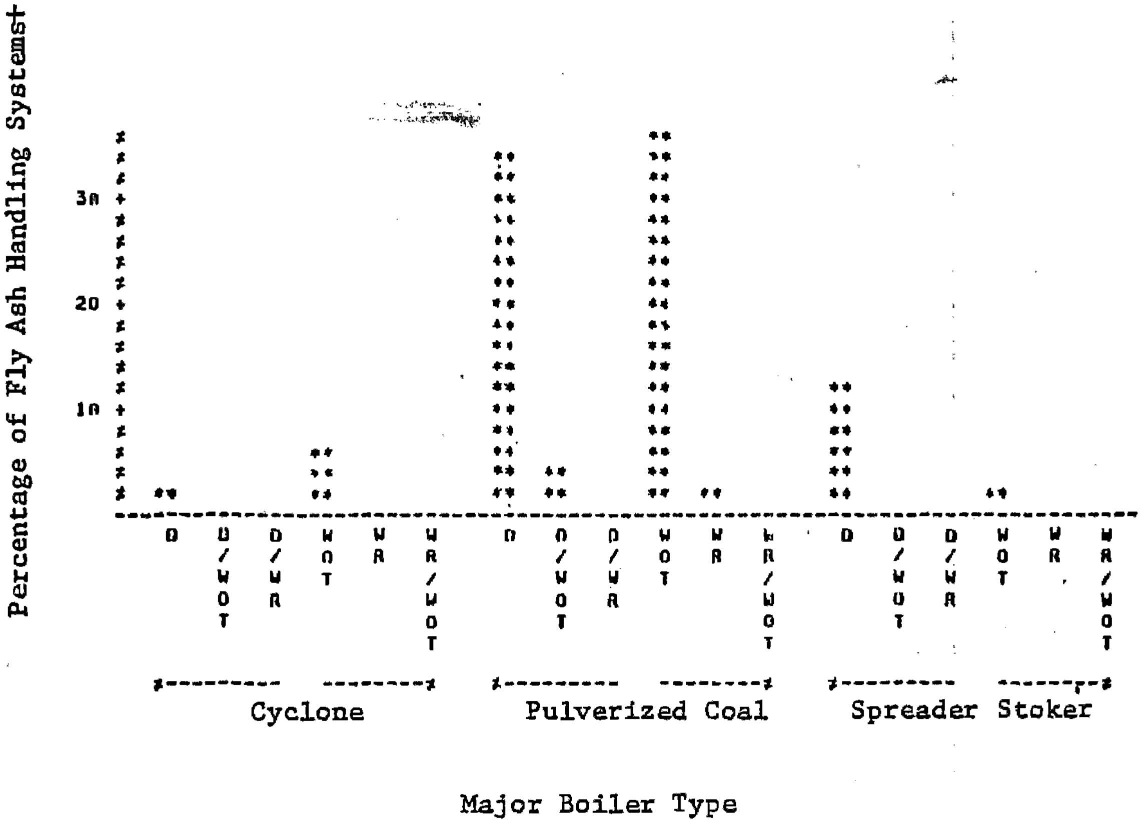


Key: D: Dry Fly Ash Handling System
WOT: Wet Once-Through Fly Ash Handling System
WR: Wet Recirculating Fly Ash Handling System

NOTE: Plants which could not be identified under a subgroup appear in a subgroup on the far left of the chart, designated by a "." or by "---".

Figure VII-26

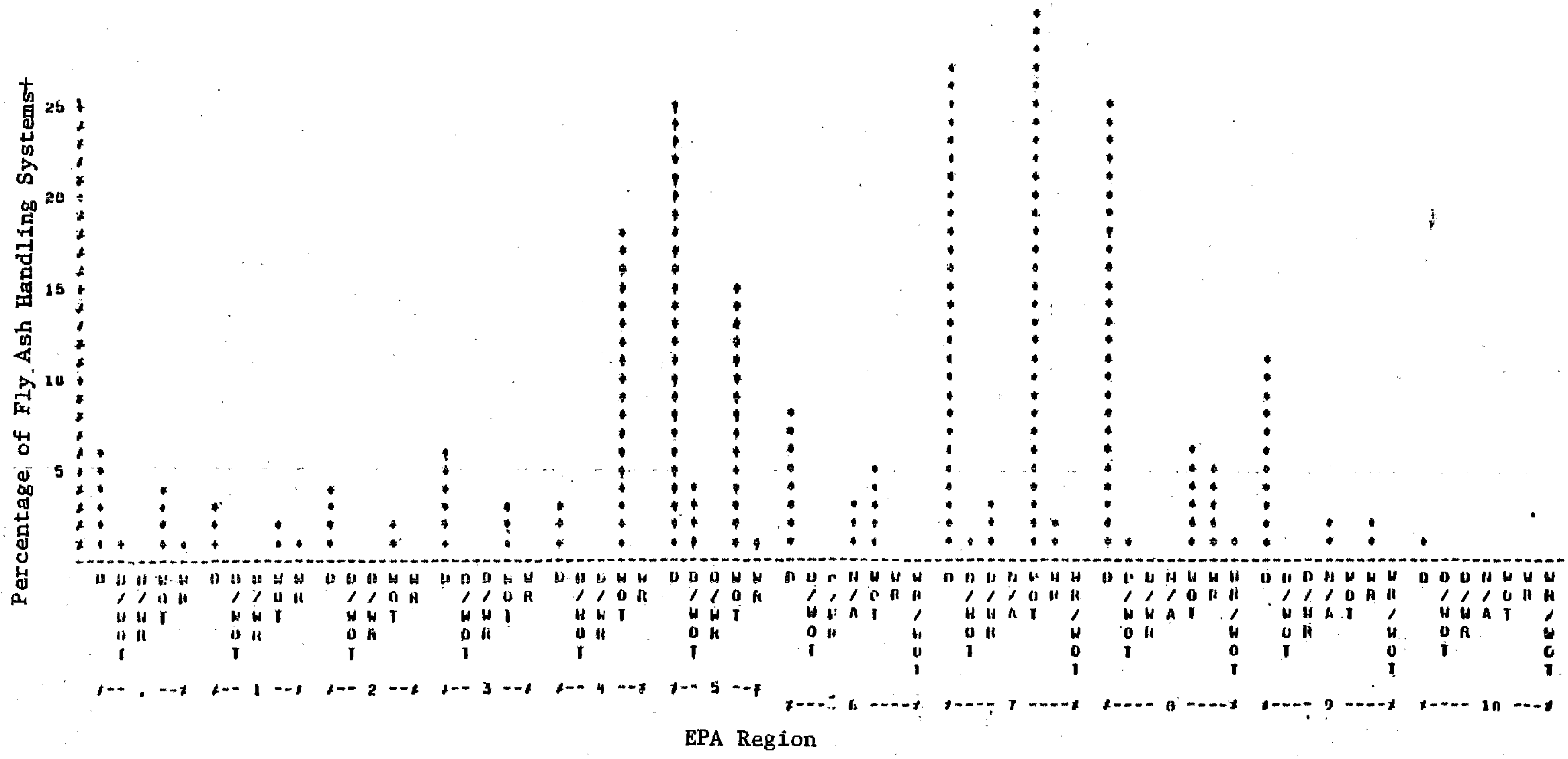
DISTRIBUTION OF FLY ASH HANDLING SYSTEMS BY COAL TYPE



Key: D: Dry Fly Ash Handling System
WOT: Wet Once-Through Fly Ash Handling System
WR: Wet Recirculating Fly Ash Handling System

NOTE: Plants which could not be identified under a subgroup appear in a subgroup on the far left of the chart, designated by a "." or by "---".

Figure VII-27
DISTRIBUTION OF FLY ASH HANDLING SYSTEMS
BY MAJOR BOILER TYPES



Key: D: Dry Fly Ash Handling System
WOT: Wet Once-Through Fly Ash Handling System
WR: Wet Recirculating Fly Ash Handling System

NOTE: Plants which could not be identified under a subgroup appear in a subgroup on the far left of the chart, designated by a "." or by "---".

Figure VII-28

DISTRIBUTION OF FLY ASH HANDLING SYSTEMS BY EPA REGION

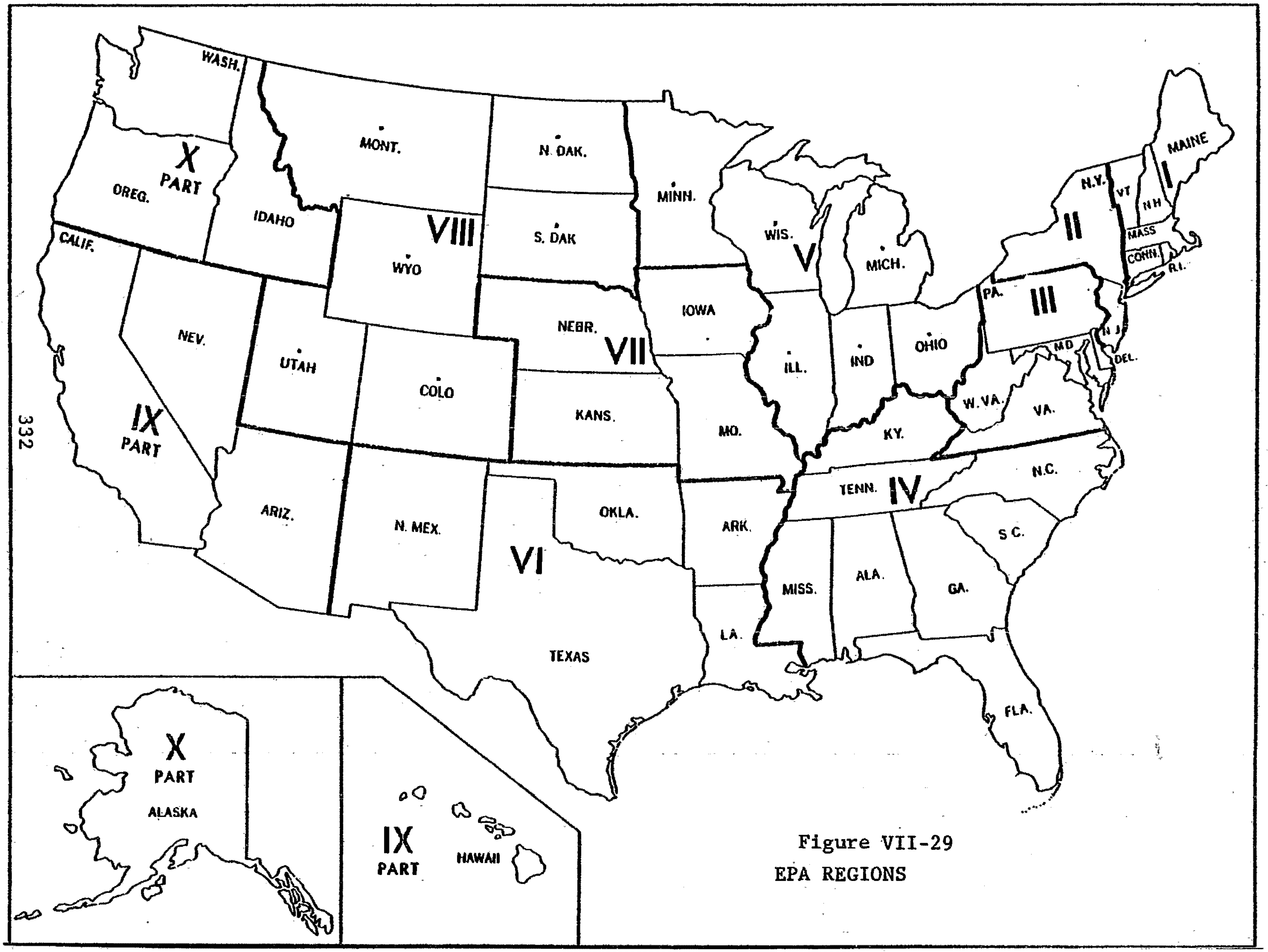

WASH.
X
PART
OREG.
IDAHO
MONT.
N. DAK.
MINN.
MAINE
I
N.Y.
VT
NH
MASS
CONN.
R.I.
II
WIS.
V
MICH.
VIII
WYO
S. DAK
CALIF.
NEV.
UTAH
COLO
NEBR.
VII
IOWA
ILL.
IND
OHIO
PA.
III
N.J.
MD
DEL.
W. VA.
VA.
KANS.
MO.
KY.
IX
PART
ARIZ.
N. MEX.
OKLA.
ARK.
TENN.
IV
N.C.
S.C.
VI
MISS.
ALA.
GA.
LA.
TEXAS
FLA.
X
PART
ALASKA
IX
PART
HAWAII

Figure VII-29

EPA REGIONS

recirculating systems. Oil-burning facilities are more common in the Northeast. The low ash production rate of oilburning *facilities* may be one explanation for the increased use of dry fly ash systems. In addition, insufficient land for ponding may also contribute to the choice of dry over wet handling.

In Region IV, wet once-through systems are most commonly used. Dry fly ash systems represent 3 percent of all ash handling systems. Wet once-through systems account for 18 percent of all ash handling systems. The high occurrence of wet once-through systems may be due in part to the greater availability of land for ponding rather than some restriction on the use of dry systems.

In Regions V, VI, and VII, dry systems are competitive with wet once-through systems.

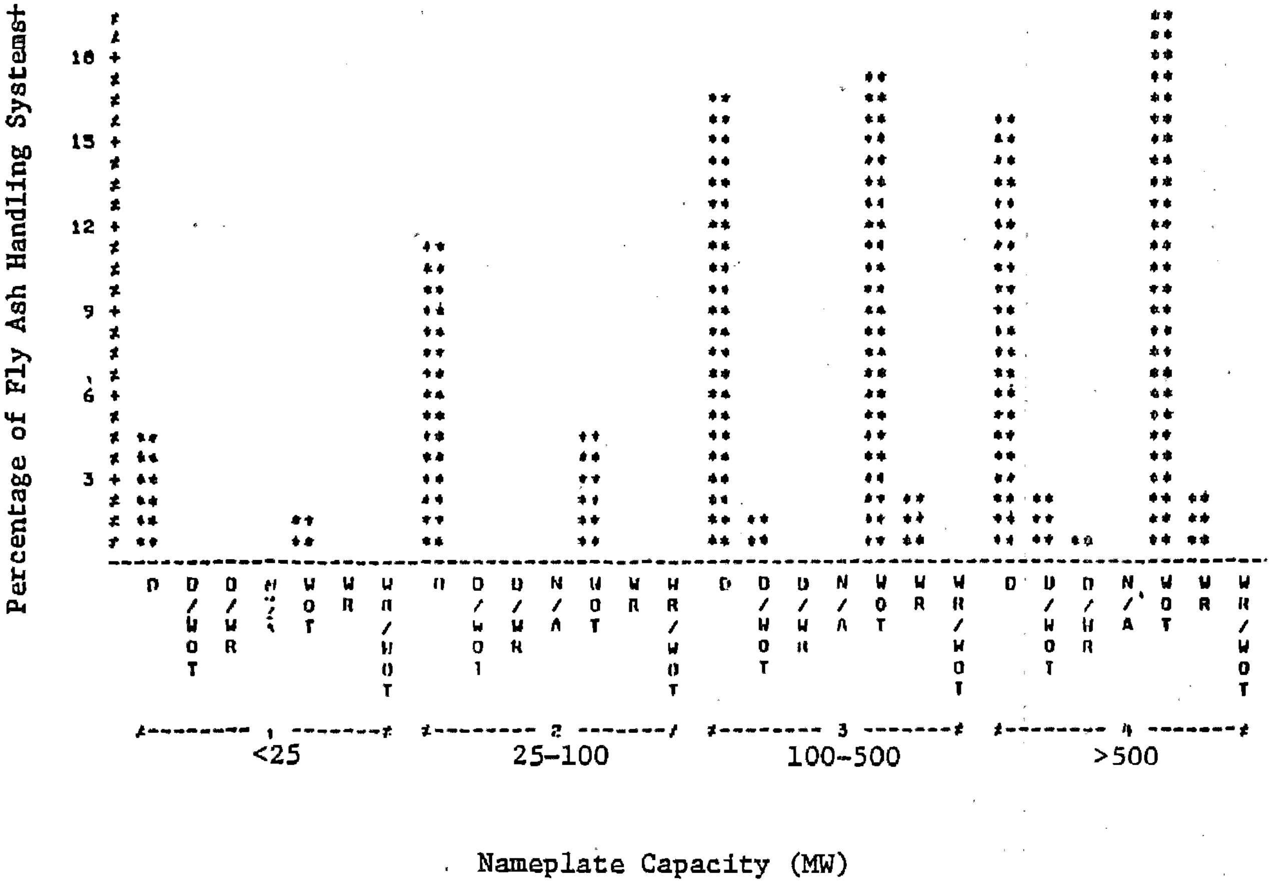
In Regions VIII and IX, the proportions of dry and wet recirculating systems are considerably higher than those of any other region. This reflects the need to conserve water in these areas. The only systems reported in Region X are dry fly ash systems. Again, this is a result of the scarcity of water in the West.

Plant Size. Plant size is expressed in plant nameplate capacity. The distribution of fly ash handling systems by various plant size catagories is presented in figure VII-30. Category 1 is dominated by dry fly ash systems. This probably reflects the dominance of stoker boilers among low capacity plants. As plant capacity increases above 100 MW, wet once-through systems become competitive with dry fly ash systems. For plants greater than 500 MW, the percentage of wet once-through is slightly greater than the percentage of dry systems.

Intake Water Quality. Intake water quality was measured as total dissolved solids (TDS). The distribution of fly ash handling systems by intake water quality is presented in figure VII-31. No significant differences in the distribution of fly ash systems are apparent among any of these categories.

Retrofitted Dry Fly Ash Systems. Table VII-14 presents a list of plants which have been identified as having retrofitted dry fly ash systems.

Partial Recirculating Systems. The wet handling of fly ash is achieved by sluicing the fly ash from the collection device, ESP or cyclone hopper, to a pond. Settling of the fly ash typically occurs in primary and secondary ponds. A third settling area, usually referred to as a clear pond, is used if the sluice water is to be recycled. Total recirculation of the ash pond transport water is a zero discharge system. If less than total recycle occurs, the system is defined as a partial recirculating system.

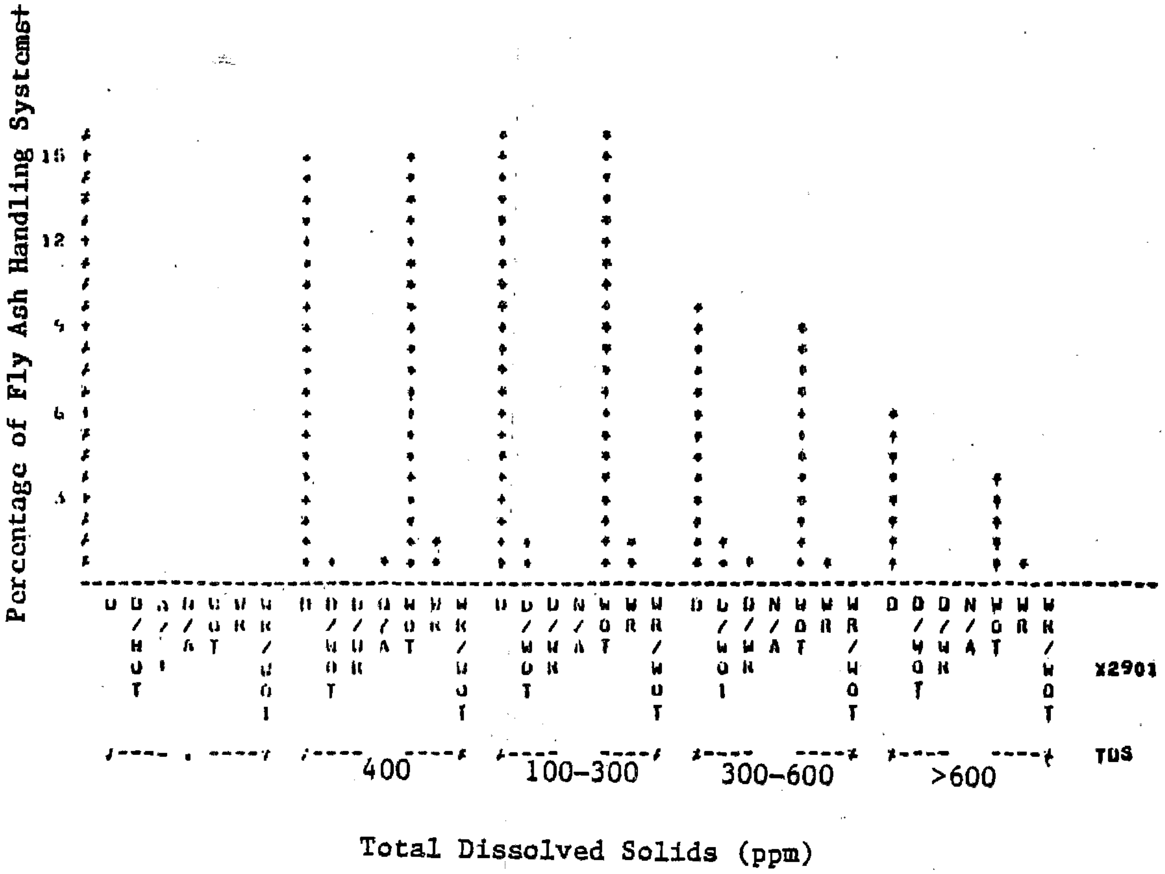


Key: D: Dry Fly Ash Handling System
WOT: Wet Once-Through Fly Ash Handling System
WR: Wet Recirculating Fly Ash Handling System

NOTE: Plants which could not be identified under a subgroup appear in a subgroup on the far left of the chart, designated by a "." or by "---".

Figure VII-30

DISTRIBUTION OF FLY ASH HANDLING SYSTEMS BY VARIOUS PLANT SIZES



Key: D: Dry Fly Ash Handling System
WOT: Wet Once-Through Fly Ash Handling System
WR: Wet Recirculating Fly Ash Handling System

NOTE: Plants which could not be identified under a subgroup appear in a subgroup on the far left of the chart, designated by a "." or by "---".

Figure VII-31
DISTRIBUTION OF FLY ASH HANDLING SYSTEMS
AS A FUNCTION OF INTAKE WATER QUALITY

Table VII-14

PLANTS WITH RETROFITTED DRY FLY ASH HANDLING SYSTEMS

Plant/Utility	Location (EPA Region)	Capacity (MW)
Gallatin/TVA	Summer, TN (IV)	1255.2
John E. Amos/ Appalachian Power Co.	Kanawha, WV (III)	2932.6
Kirk/Black Hills Power & Light Co.	Lead, SD (VIII)	31.5
Ben French/Black Hills Power & Light Co.	Rapid City, SD (VIII)	22.0
Fisk/Commonwealth Edison Co.	Cook, IL (V)	547.0
Bailly/No. Indiana Public Service Co.	Porter, IN (V)	615.6
Ashtabula/Cleveland Electric Illuminating Co.	Ashtabula, OH (V)	640.0
Avon Lake/Cleveland Electric Illuminating Co.	Lorain, OH (V)	1,275.0
Eastlake/Cleveland Electric Illuminating Co.	Lake, OH (V)	1,257.0
Lake Shore/Cleveland Electric Illuminating Co.	Cuyahoga, OH (V)	514.0
Coffeen/Central Illinois Public Service	Montgomery, IL (V)	1,005.5
Reid Gardner/Nevada Power Co.	Moapa Clark Co., NV (IX)	340.8
Hayden/Colorado-Ute	Hayden, CO (VIII)	447.0
Cherokee #3/Public Service of Colorado	Adams, CO (VIII)	801.3
Bowen/Georgia Power Company	Bartow, GA (IV)	2,547.0
Arkwright/Georgia Power Co.	Bibb, GA (IV)	181.0
McDonough/Georgia Power Company	Cobb, GA (IV)	598.0
Port Wentworth/ Savannah Electric & Light	Chatham, GA (IV)	333.9

Partial Recirculating Systems

Process Description. A generalized schematic of a typical partial recirculating system is shown in figure VII-32. Sluiced ash is pumped to the primary and secondary pond and flows to the clear pond from which water is recirculated by the main recirculation pumps to the main sluice pumps to be used as dilution water. A portion of the clear pond overflow is discharged.

There are various methods of sluicing the fly ash from the collection point. A typical method is illustrated in figure VII-33. Fly ash from the ESP hoppers is vacuum conveyed through the vacuum producer where it is slurried with the high-pressure water used to create the vacuum for conveying. This slurry is discharged through an air separator. From the air separator, the sluiced fly ash may flow by gravity to the pond or to a mix tank before it is pumped to the pond site. Slurry pumps are necessary when the ash slurry is pumped a great distance to the pond, which is often the case. Many ponds are typically 1,000 to 3,000 feet from the hoppers.

Equipment. The equipment associated with dry conveying, i.e., all equipment up to and including the vacuum producer, is discussed in the sections on dry fly ash handling. The major equipment discussed in this section includes:

- air separator,
- pumps,
- conveying pipe, and
- ponds.

Air Separator. A typical air separator is shown in figure VII-34. A wide variety of separators, unlined or with basalt linings, are available for single and multiple systems.

Pumps. Slurry pumps may be centrifugal pumps or ejectors (jet pumps). Either pump requires considerable dilution at the suction in order to provide a slurry that can be pumped. For the same discharge quantity and discharge head, a centrifugal pump is about 40 percent more efficient than a jet pump without considering the efficiency of auxiliary pumping equipment which supplies the ejector nozzle (40). Jet pumps are generally more favorable for slurry handling than centrifugal pumps because of the relative ease with which they can be serviced, even though such service may be required much more frequently than for a comparable centrifugal pump. The higher maintenance requirement is due to higher operating pressure in the ejector nozzles.

Hard metals are employed in the construction of both types of pumps in areas where abrasion is most severe. It is desirable to maintain velocities as low as possible within the limits of pump efficiency to

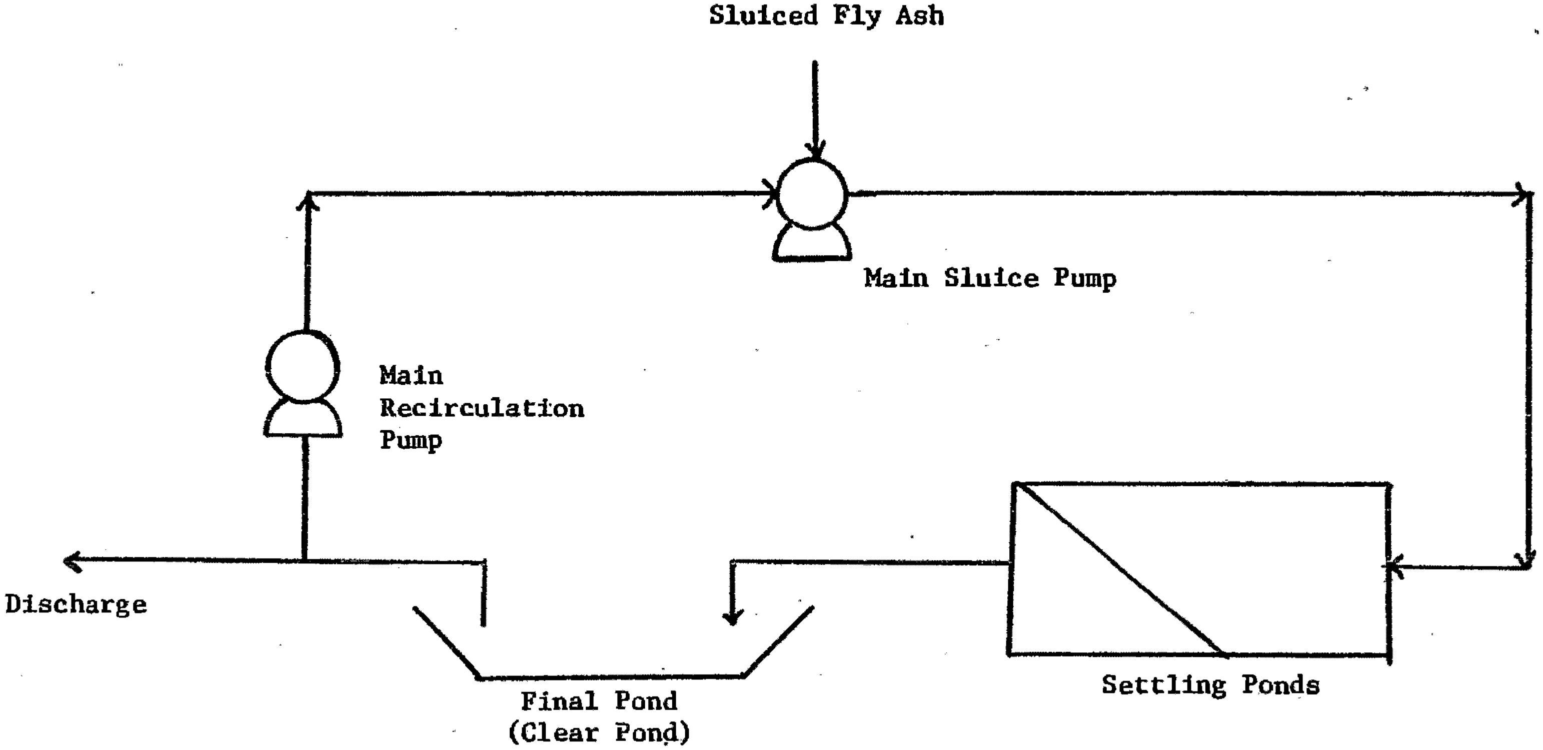

Sluiced Fly Ash
Main Sluice Pump
Main Recirculation Pump
Discharge
Final Pond (Clear Pond)
Settling Ponds

Figure VII-32
GENERALIZED, SCHEMATIC DIAGRAM OF A PARTIAL RECIRCULATION FLY ASH HANDLING SYSTEM

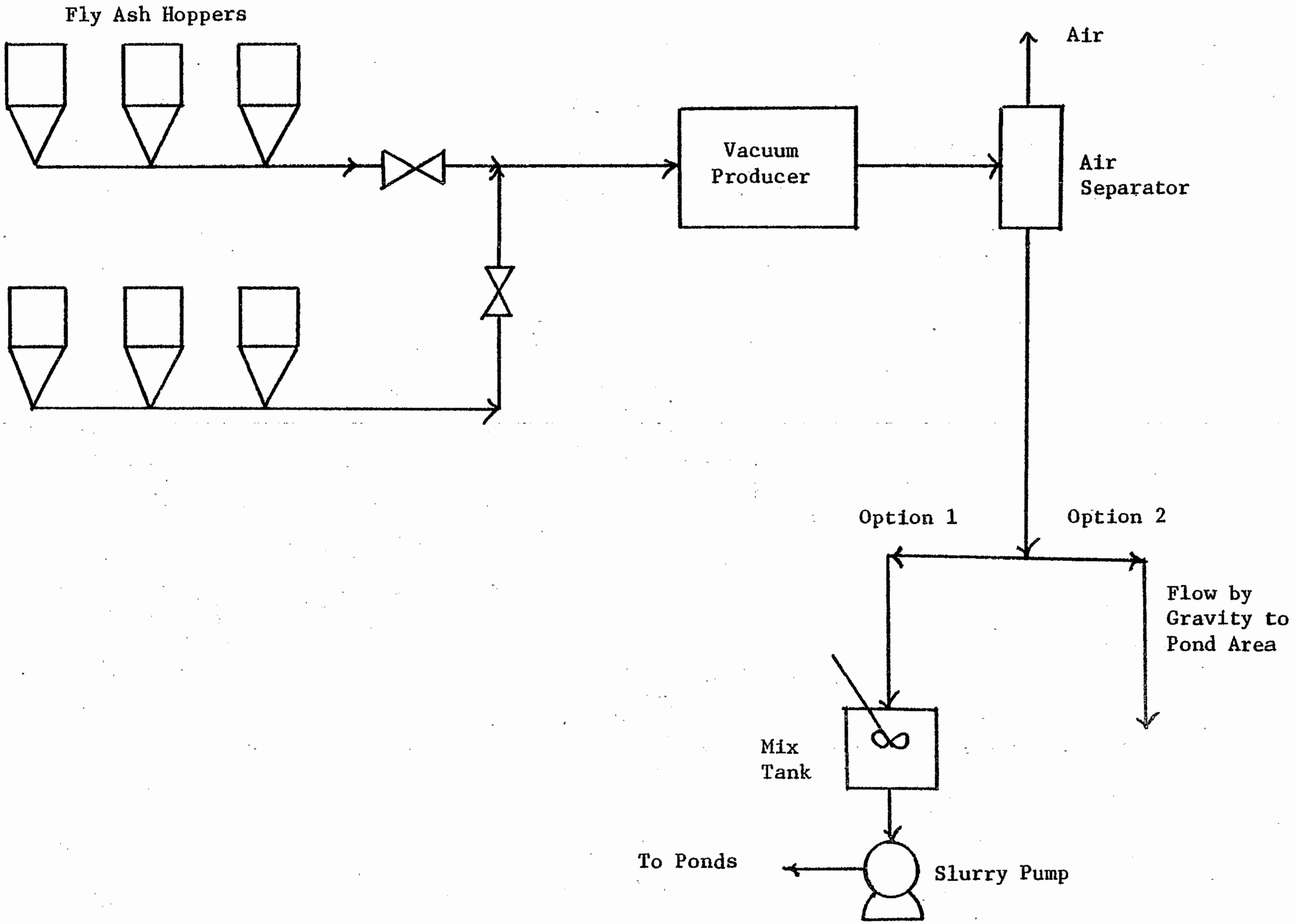

Fly Ash Hoppers
Air
Vacuum Producer
Air Separator
Option 1
Option 2
Flow by Gravity to Pond Area
Mix Tank
To Ponds
Slurry Pump

Figure VII-33
A TYPICAL METHOD OF SLUICING FLY ASH FROM COLLECTION POINTS

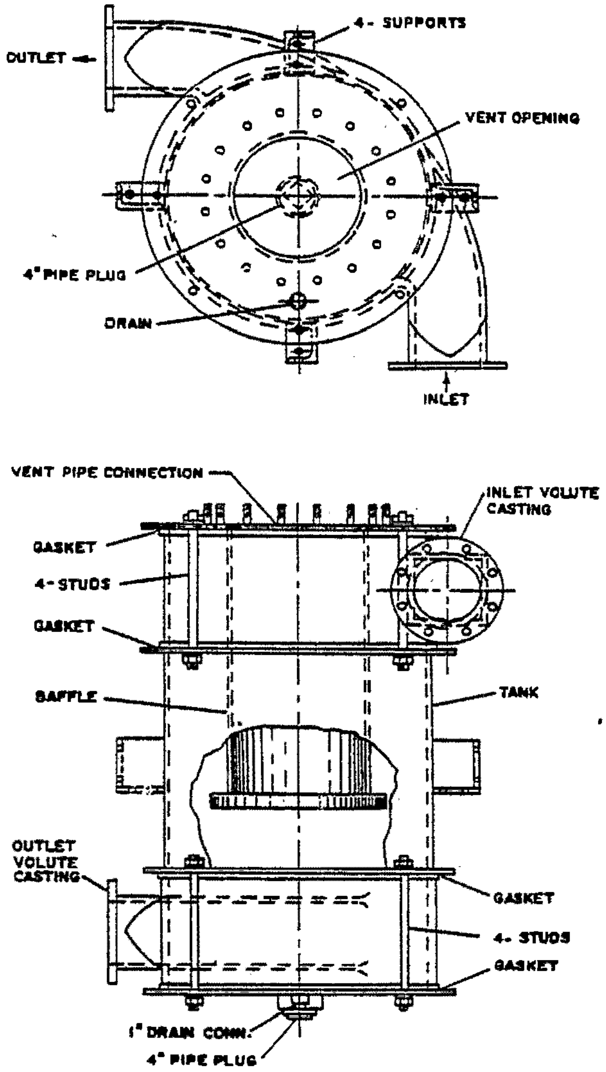

4- SUPPORTS
OUTLET
VENT OPENING
4" PIPE PLUG
DRAIN
INLET
VENT PIPE CONNECTION
INLET VOLUTE CASTING
GASKET
4-STUDS
GASKET
BAFFLE
TANK
OUTLET VOLUTE CASTING
GASKET
4- STUDS
GASKET
1" DRAIN CONN.
4" PIPE PLUG

Figure VII-34
TYPICAL AIR SEPARATOR IN A PARTIAL RECIRCULATING FLY ASH HANDLING SYSTEM

Reprinted from A Primer for Ash Handling by Allen-Sherman-Hoff Company by permission of Allen-Sherman-Hoff Company, a Division of Ecolaire. Year of first publication: 1976.

reduce abrasion. A veloctiy of 40 to 50 feet per second maximum through a jet pump is desirable. In the *case of centrifugal pumps,* the impeller peripheral speed should not exceed 4,500 to 5,000 feet per minute (40).

When system heads exceed about 100 feet, jet pumps are generally ineffective since series pumping is not practical. Centrifugal pumps, on the other hand, can be conveniently placed in series for high-head requirements (40).

Centrifugal pumps are generally used for recirculation. Clarity of recirculated water does not present a wear problem to a centrifugal ash handling pump.

Pipe. The pipe conveying an ash slurry is similar to that used in dry fly ash systems. Basic pipe for ash handling service has a Brinnell Hardness Number (BHN) of 200; fittings have a BHN around 400. Various hardnesses are available with cost usually increasing in proportion to hardness (40). Centrifugally cast iron pipe is by far the most widely used pipe for wet systems because of its ability to withstand the corrosive and erosive condition often encountered in ash handling (39). This type of pipe is available from a number of pipe manufacturers. Basalt- lined pipe is another fairly common pipe used in ash handling systems. The basalt lining is formed from volcanic rock which is melted and shaped into a liner for the pipe. Basalt provides improved protection from abrasion; however, it is generally less resistant to impact caused by turbulent conditions at bends in the pipe. In fact, some plants have used basalt-lined pipes for straight sections and cast iron for bends. Basalt also protects against corrosion by sealing the pipe from the corrosive conditions within. One drawback from this pipe is that it is more expensive to install because it requires a lot of shaping and cutting. Some firms are marketing a ceramic pipe for use in ash handling systems. This type of pipe is fairly new and has not been universally accepted by the utility companies. Fiberglass pipe has also been used in ash handling systems. Like basalt- lined pipe, fiberglass pipe has fairly high installation costs because it requires cutting and shaping.

Ponds. The primary pond or settling area may not necessarily be a pond, per se, but can be a run-off area for removal of the larger ash particles. The sluice water may then overflow via gravity to a secondary pond for further settling. Overflow from the second pond would flow to a clear pond which serves as a holding basin for recirculation water. To be effective, ponds must cover a considerable area to allow sufficient retention time for settling of the ash in the conveying water. For bottom ash, volume in the storage basin should be sufficient to provide at least 1 day's retention time. Because of its slow settling rate, fly ash requires a larger pond to provide longer retention time than for bottom ash.

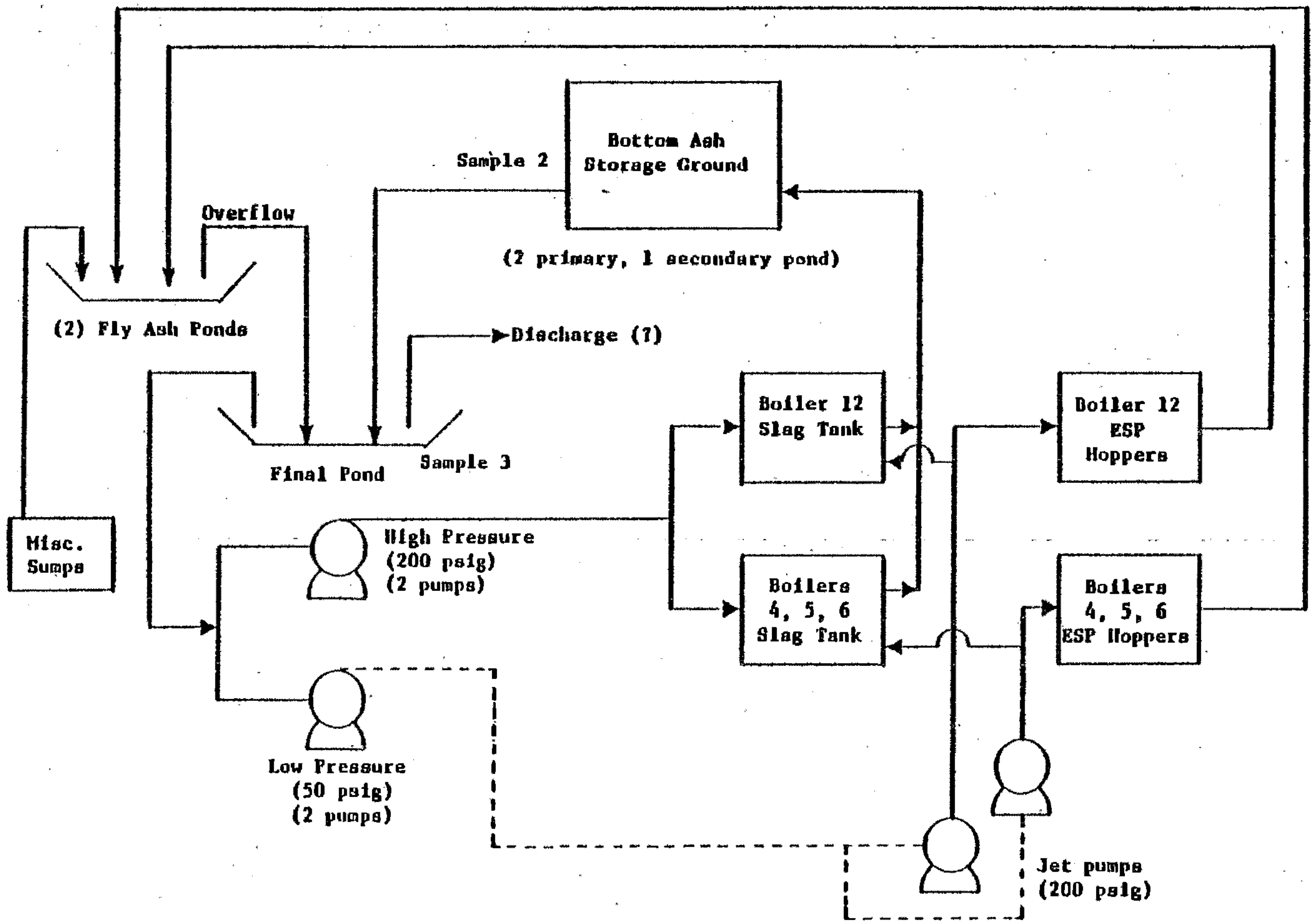
Maintenance. For those sections of a partial recirculating system which involve dry conveying, maintenance of the equipment is the same as for vacuum and pressure dry fly ash handling systems. Abrasive and corrosive wear on the pumps and conveying lines handling the ash sluice is a major source of maintenance problems. Most of the wear on pipe lines occurs along the bottom because most of the solids in the slurry are carried along the bottom. To distribute the wear along the bottom, many plants rotate their cast iron pipe lines regularly. The other area of major maintenance are the settling ponds. Generally, these ponds must be dredged regularly to remove settled ash for landfill disposal.

Retrofitting. The motivation for retrofitting a partial recirculating system onto an existing ash pond system may be either a water shortage or regulations governing wastewater effluents. Essentially no equipment must be removed in order to retrofit a partial recirculating system other than rerouting of old pipe near the sluicing pumps where hook up would occur. Old pipe in the plant may be used in some instance to help defray the capital cost of the new pipe. Recirculation pumps may be required to move the pond water to the existing ash sluice pumps. Some downtime may be required for hook up of the recycle line to the main sluice water conveying pumps.

Trip Report. One of the plants visited in the effort to define various bottom ash and fly ash handling practices had a partial recirculating system for fly ash. Plant 1809 is a 736 MW electric power generating station. Four of the seven boilers currently in operation burn bituminous coal from Bureau of Mines Districts 10 and 11 with an ash content of 10 to 12 percent. The boilers are of the wet bottom, cyclone type and produce a relatively large amount of bottom ash slag. The plant utilizes a wet recirculating ponding system to handle both fly ash and bottom ash. Water is obtained from a nearby creek for use in the sluicing operation. Figure VII-35 presents a flow diagram indicating separate fly ash and bottom ash holding ponds. There are two primary, two secondary, and one final pond.

The fly ash is jet sluiced from the ESP hoppers from Units 4, 5, 6, and 12 to one of two fly ash settling ponds. The sluice water from the fly ash pond is overflowed by gravity to the final pond for holding and recirculation to the jet pumps and ESP hoppers. The final pond also contains bottom ash sluice water. The same discharge point exists for the fly ash system as for the bottom ash. The final pond and recycle lines were retrofitted in 1974 in order to collect the discharge streams in one location for treatment purposes. The distance from the ESP hoppers to the fly ash ponds is approximately 1,500 feet. The fly ash is sluiced six times a day in 12-inch diameter sluice lines of cast basalt construction for 45-minute sluicing intervals. Thirty fly ash hoppers collect the fly ash at the ESP for Unit 12 and 12 hoppers collect for Units 4, 5, and 6.

Since the coal-fired boilers are all cyclone type, a small percentage of fly ash is produced relative to the bottom ash. In 1978, approximately 48,600 tons of fly ash was produced which represents 26 percent of all the ash produced. This fly ash is cleaned out of one pond annually and is trucked to a landfill site by an outside firm.


Bottom Ash Storage Ground
Sample 2
(2 primary, 1 secondary pond)
Overflow
(2) Fly Ash Ponds
Discharge (?)
Final Pond
Sample 3
Boiler 12 Slag Tank
Boiler 12 ESP Hoppers
Misc. Sumps
High Pressure (200 psig) (2 pumps)
Boilers 4, 5, 6 Slag Tank
Boilers 4, 5, 6 ESP Hoppers
Low Pressure (50 psig) (2 pumps)
Jet pumps (200 psig)

NOTE: Approximately 1/4 mile from slag tanks and ESP hoppers to the pond area.

Figure VII-35

ASH HANDLING SYSTEM FLOW DIAGRAM AND SAMPLING LOCATIONS FOR PLANT 1809

The sluicing jets and recirculation pumps are the primary maintenance items for this system. Minor erosion has caused some maintenance problems. Scaling and corrosion have not been found to be prevalent.

Physical/Chemical Treatment of Fly Ash Pond Overflows from Wet, Once-Through Systems

Wet, once-through systems with ponding are commonly used for ash handling. Typically, sluiced fly ash is sent to primary and secondary ponds arranged in series where settling of the larger particles occurs. The overflow from the secondary pond is then discharged. Physical/chemical treatment of the ash pond overflow may be employed to remove trace metals before the sluice water is discharged. This section describes physical/chemical treatment and the equipment involved and assesses the effectiveness of physical/chemical treatment in removing arsenic, nickel, zinc, copper, and selenium from ash pond overflows.

Process Description. Metals typically are removed from wastewater by raising the pH of the wastewater to precipitate them out as hydroxides. Lime is frequently used for pH adjustment. A flow diagram of a typical physical/ chemical treatment system for metals removal using lime is shown in figure VII-36. The major equipment items include a lime feed system, mix tank polymer feed system, flocculator/clarifier, deep bed filter, acid feed system, and another mix tank. The underflow from the clarifier may require additional treatment with a gravity thickener and a vacuum filter to provide sludge which can be transported economically for landfill disposal. Typically, wastewater pH's of 9 to 12 are required to achieve the desired precipitation levels. Lime dosage rates, flocculant dosage rates, and clarifier design parameters are determined by jar tests and onsite pilot test on the ash sluice water discharge.

Equipment. Typically, hydrated or pebble lime is used to raise low pH systems to the desired pH. Hydrate lime feed systems are used when lime feed rates are less than 250 pounds per hour (41). Pebble lime feed systems are used for lime feed rates greater than 250 pounds per hour. A typical pebble lime feed system is illustrated in figure VII-37. For larger systems, the reduced chemical cost and ease of handling of pebble lime make the pebble lime systems more desirable.

Wastewaters which have a pH greater than 9 after lime addition will require acid addition to reduce the pH before final discharge. The system differs from lime feed systems in that the acid is delivered to the plant as a liquid. The feed system equipment must be constructed of special materials, typically rubber or plastic-lined carbon steel or stainless steel alloys. Acid addition rates for pH adjustment are highly dependent upon wastewater flow, pH, alkalinity, and type and strength of acid. Dosage rates are determined by laboratory or onsite testing.

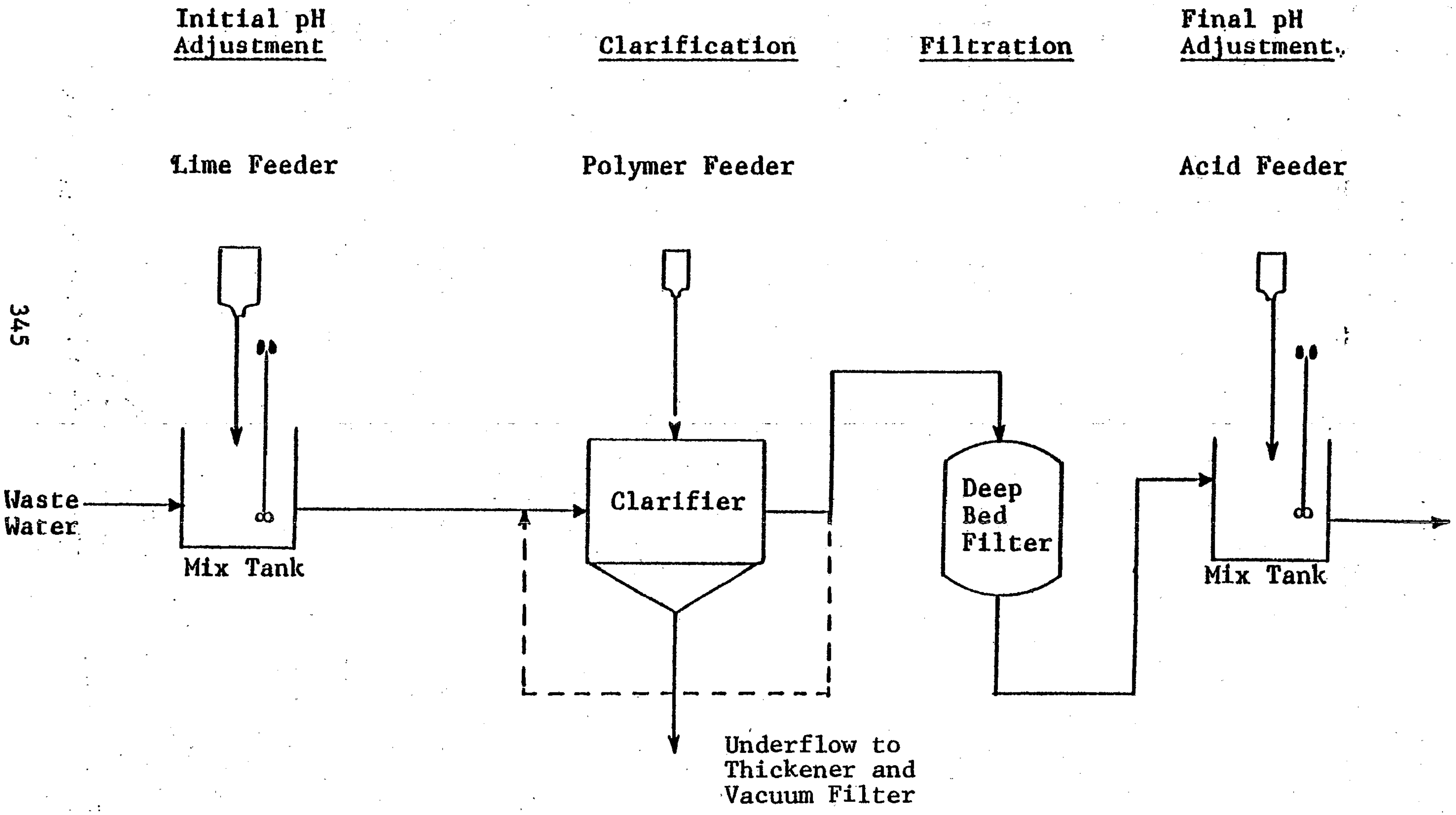

Initial pH Adjustment
Clarification
Filtration
Final pH Adjustment
Lime Feeder
Polymer Feeder
Acid Feeder
Waste Water
Mix Tank
Clarifier
Deep Bed Filter
Mix Tank
Underflow to Thickener and Vacuum Filter

Figure VII-36

FLOW DIAGRAM OF A TYPICAL PHYSICAL/CHEMICAL TREATMENT SYSTEM FOR METALS REMOVAL USING LIME

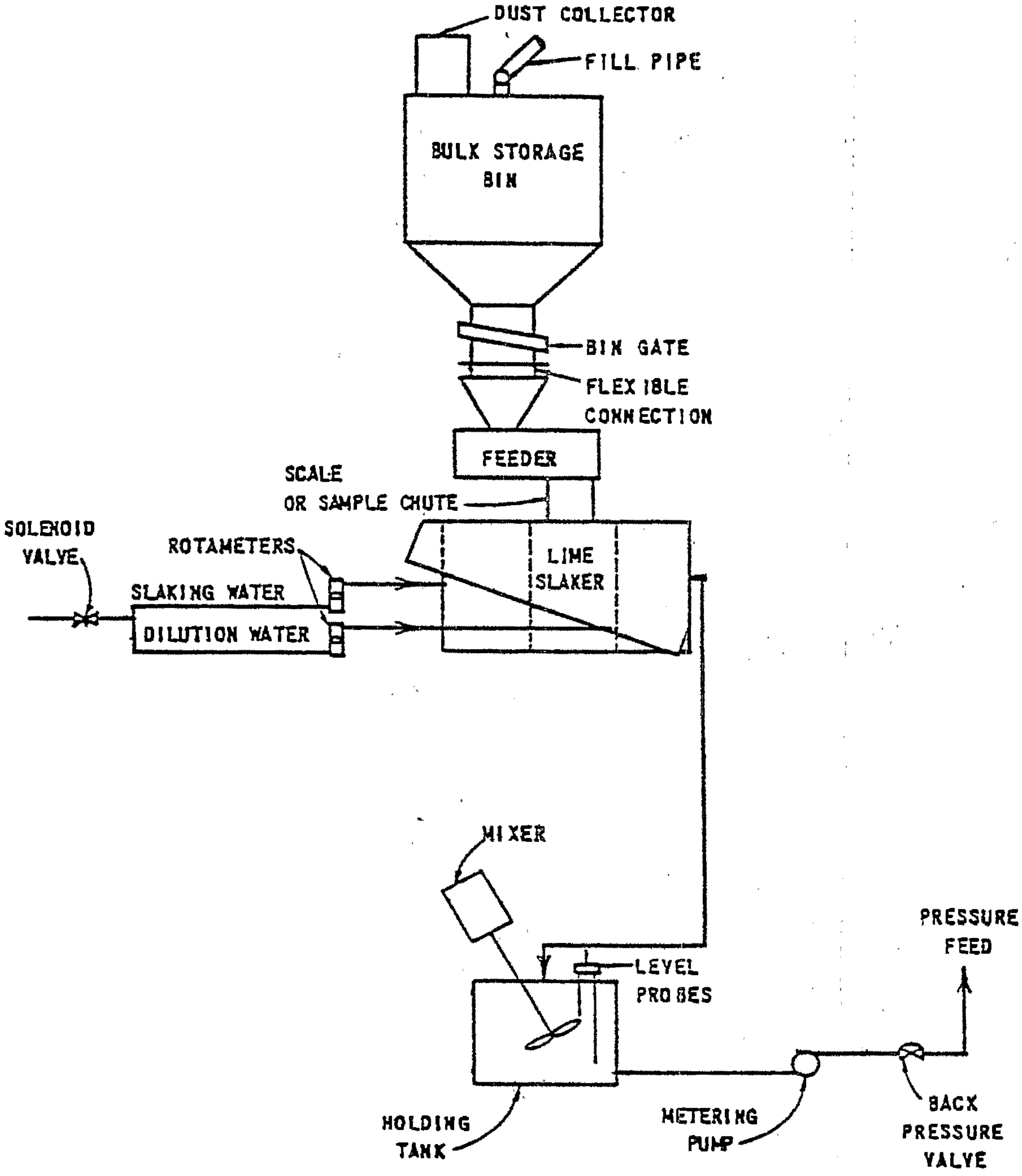

DUST COLLECTOR
FILL PIPE
BULK STORAGE BIN
BIN GATE
FLEXIBLE CONNECTION
FEEDER
SCALE OR SAMPLE CHUTE
SOLENOID VALVE
ROTAMETERS
SLAKING WATER
DILUTION WATER
LIME SLAKER
MIXER
PRESSURE FEED
LEVEL PROBES
HOLDING TANK
METERING PUMP
BACK PRESSURE VALVE

Figure VII-37
TYPICAL LIME FEED SYSTEM (41)

For wastewaters which have a pH of less than 6, mixers and mixing tanks are made of special materials of construction (*stainless steel* or lined-carbon steel). For wastewaters with pH's greater than 6, concrete tanks are typically used.

Polymer addition may be required to enhance the settling characteristics of the metal hydroxide precipitate. Typical polymer feed concentrations in the wastewater are 1 to 4 ppm. The required polymer addition rate is determined using laboratory or onsite testing.

The metal hydroxide precipitate is separated from the wastewater in the clarifier. Unlike settling ponds, these units continually collect and remove the sludge formed. To determine the size of the unit required, laboratory settling tests are required. These tests will define the required surface area. Typically, a 2- to 3-hour wastewater retention time will be required (39). Clarifier diameters range from 10 to 200 feet with average depths of 10 to 15 feet (39).

Filters are typically used for effluent polishing and can reduce suspended solids levels below 10 mg/l. Figure VII-38 illustrates a typical deep bed filter. Sand or coal are the most common filter media. Hydraulic loading rates of 2 to 20 gpm per square foot of bed cross sectional area are common. High removal efficiencies require lower hydraulic loading rates. For general design purposes, a hydraulic loading of 5 gpm per square foot of filter area is typical. As the filter medium becomes plugged with suspended solids, the pressure drop across the bed increases. At 10 to 15 psi bed differential pressure, the bed is automatically backwashed with water and air to remove the trapped suspended solids. Typically, 6 to 8 scfm of air and 6 to 8 gpm of water are required to backwash a square foot of bed cross section. Total backwash water consumption is usually in the range of 150 to 200 gallons per square foot of filter surface area. Backwash frequency can range from 1 to 6 times per day for normal operations. For backwash systems using only water, 15 to 20 gpm per square foot of filter area is requred with a backwash water rate of 400 to 500 gallons per square foot of filter area (39).

Gravity thickeners are essentially identical to clarifiers in design. Sludge enters the middle of the thickener and the solids settle into a sludge blanket at the bottom. The concentrated sludge is very gently agitated by a moving rake which dislodges gas bubbles and keeps the sludge moving to the center well through which it is removed. The average retention time of solids in the thickener is between 0.5 and 2 days (42). Most continuous thickeners are circular and are designed with depths of 10 feet (42). In thickening of lime sludge from lime tertiary treatment, incoming sludge of 1 to 2 percent solids has been thickened to 8 to 20 percent solids at solids loadings

Vacuum filtration is a common technique for dewatering sludge to produce a cake that has good handling properties and minimum volume. The vacuum filter typically consists of a cylindrical drum that rotates with the lower portion of the drum submerged in the feed sludge. The drum is covered with a porous filter medium. As the drum

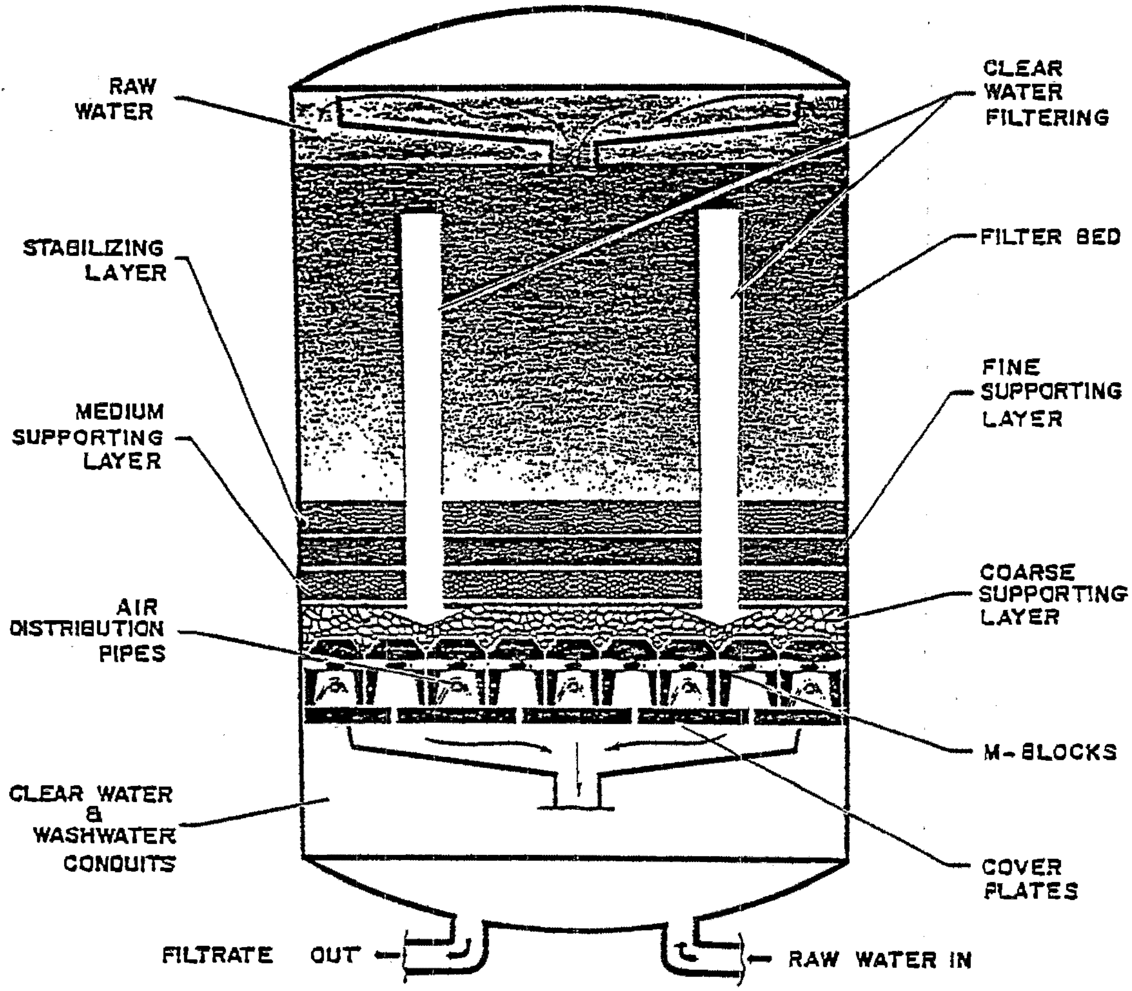

RAW WATER
STABILIZING LAYER
MEDIUM SUPPORTING LAYER
AIR DISTRIBUTION PIPES
CLEAR WATER & WASHWATER CONDUITS
FILTRATE OUT
CLEAR WATER FILTERING
FILTER BED
FINE SUPPORTING LAYER
COARSE SUPPORTING LAYER
M-BLOCKS
COVER PLATES
RAW WATER IN

Figure VII-38
DEEP BED FILTER

rotates, the feed liquor is drawn onto the filter surface by a vacuum that exists on the drum interior. The liquid passes through the filter and the sludge forms a cake on the surface of the drum. The cake is separated from the filter by a scraper. Generally, vacuum filters are capable of dewatering a 2 to 4 percent solids feed to a filter cake with a concentration of 19 to 36 percent solids. Typical solids loading rates may vary from 3 to 14 pounds per hour per square foot for lime sludges.

Effectiveness. A review of the literature on trace metals removal from various wastewaters using physical/chemical treatment was conducted for arsenic, nickel, zinc, copper, and selenium. The results of this literature review and the results of bench-scale studies of trace metal removals in ash pond overflows are discussed in this subsection.

Arsenic. Arsenic and arsenical compounds have been reported as waste products of the metallurgical industry, pesticide production, petroleum refining, and the rare-earth industry. High levels of arsenic also have been reported in raw municipal wastewater. Arsenic occurs in four oxidation states, but it is found primarily in the trivalent (arsenite) and pentavalent (arsenate) forms. It is found in organic and inorganic compounds. The inorganic compounds are generally more hazardous than the organic compounds, and the trivalent form is generally more toxic than the pentavalent form. Information on the conventional coagulant and lime-softening processes indicates that removal is valance dependent (44).

While only limited information is available on the concentration of arsenic in industrial wastewater and on current treatment processes, more up-to-date information is available on the removal of arsenic in municipal wastewater. One study (45) of the lime softening process indicates removals of approximately 85 percent. In particular, the lime softening process was found to reduce an initial arsenic concentration of 0.2 mg/l down to 0.03 mg/l. Simple filtration through a charcoal bed reduced the same initial arsenic concentration to 0.06 mg/l. Results from another pilot plant study (45) for removal of arsenic in municipal wastewaters indicate removal efficiencies of 96 to 98 percent (final effluent concentration = 0.06 mg/l). The treatment involved addition of coagulant (ferric sulfate), followed by flocculation, settling, dual media filtration, and carbon adsorption.

The Water Supply Research Division (WSRD) of EPA recently completed pilot plant studies on arsenic removal (44). In one study, sample effluents were pumped to a rapid-mix tank then flowed by gravity through coagulation, flocculation, and sedimentation steps to filter columns. WSRD reported removals as high as 96 percent for an initial concentration of 0.39 mg/l of arsenate and 82 percent for an initial concentration of 0.12 mg/l of arsenite. The study confirmed that:

- Arsenic V is more easily removed than Arsenic III by alum and ferric sulfate coagulation.

- Ferric sulfate is more effective for removal of Arsenic III.

The average removal efficiency of Arsenic V was approximately 69 percent (minimum removal = 11 percent, maximum removal = 96 percent). The average removal efficiency of Arsenic III was approximately 48 percent (minimum removal = 1 percent, maximum removal = 82 percent). WSRD also investigated the use of lime softening techniques. Removals of 71 percent for Arsenic III and 99 percent for Arsenic V were reported after settling and dual-media filtration. The average removal efficiency for Arsenic III was about 50 percent; and for Arsenic V, about 76 percent.

In pilot plant studies in Taiwan, the only technique continuously capable of high arsenic removal was ferric chloride coagulation, preceded by chlorine oxidation (for oxidation of Arsenic III to Arsenic V), followed by sedimentation and filtration (44). Based on these studies, a full-scale arsenic removal plant for treatment of municipal wastewater, handling 150 m_3/day, was built in Taiwan. During the first 59 days of operation, 82 to 100 percent removal was achieved (with initial concentrations from 0.60 to 0.94 mg/l).

In a bench scale study conducted for EPA of priority heavy metals removal, chemical precipitation was evaluated for arsenic removal from three ash pond effluents (48). This treatment method proved effective in reducing arsenic to the analytical detection limit. The results of this study are presented in greater detail later in this section.

A summary of arsenic treatment methods and removals is shown in table VII-15.

Nickel. Wastewaters containing nickel are found primarily in the metal industries, particularly in plating operations. A list of industries and their average wastewater nickel concentrations is given in table VII-16. Nickel exists in wastewater as the soluble ion. In the presence of complexing agents such as cyanide, nickel may exist in a more soluble complexed form; therefore, pretreatment to remove these agents may be necessary. The formation and precipitation of nickel hydroxide is generally the basis for destructive treatment of nickel wastes (as opposed to carbonates and sulfates, which are used in the recovery of nickel). Table VII-17 summarizes actual full-scale results of lime precipitation. The theoretical solubility limit for nickel is approximately 0.001 mg/l (46). Complete removal of nickel has been reported with ion exchange treatments. Though this is generally more expensive, the cost is offset by the value of the recovered nickel. Since recovery of nickel from ash pond effluents is not practical, such a treatment would probably be uneconomical for steam electric powerplants.

Pilot plant studies (45) have been conducted on the use of reverse osmosis for removal of nickel from wastewater. The studies indicate removals of greater than 99 percent. It should be noted, however, that reverse osmosis units typically blowdown 10 to 40 percent of the

Table VII-15

ARSENIC REMOVAL FROM MUNICIPAL WASTEWATERS (44, 45)

Treatment Method	Initial Arsenic Concentration (mg/l)	Final Arsenic Concentration (mg/l)	Percent Removal
Lime Softening	0.2	0.03	85
Lime Softening			
As V	0.58	----	99
As III	0.34	0.10	71
Coagulation with Ferric Chloride	1.5-3.0	0.06	96-98
Coagulation with Ferric Chloride			
As V	0.39	0.02	96
As III	0.12	0.02	82
Chlorine Oxidation and Ferric Chloride Coagulation	0.06-0.94	----	82-100
Charcoal Filtration	0.2	0.06	70

Table VII-16

SUMMARY OF NICKEL CONCENTRATIONS IN METAL PROCESSING AND PLATING WASTEWATERS (45)

(mg/l)

Industry	Nickel Concentration	
	Range	Average
Tableware Plating		
Silver bearing waste	0-30	5
Acid Waste	10-130	33
Alkaline waste	0.4-3.2	1.9
Metal Finishing		
Mixed wastes	17-51	-
Acid wastes	12-48	-
Alkaline wastes	2-21	-
Small parts fabrication	179-184	181
Combined degreasing, pickling and Ni dipping of sheet steel	3-5	-
Business Machine Manufacture		
Plating wastes	5-35	11
Pickling wastes	6-32	17
Plating Plants		
4 different plants	2-205	-
Rinse waters	2-900	-
Large plants	up to 200	25
5 different plants	5-58	24
Large plating plant	88 (single waste stream)	-
	46 (combined flow)	-
Automatic plating of Zinc base castings	45-55	-
Automatic plating of ABS type plastics	30-40	-
Manual barrel and rack	15-25	-

Table VII-17

SUMMARY OF EFFLUENT NICKEL CONCENTRATIONS AFTER PRECIPITATION THREATMENT (45)

Source	Nickel Concentration (mg/l)		Precent Removal	Comment
	Initial	Final		
Tableware Plating	21	0.09-1.9	91-99.6	$FeCl_3$ + Sand Filtration
Appliacne Manufacutring	35	0.4	98.9	----
Office Machine Manufacutring	39	0.17	99.6	
Non-Ferrous Metal	--	0.5-0.13	----	6 hour Works settling
Plating	46	0.8		6 hour detention in clarifier
Record Changer Manufacturing	--	0.1-0.2	----	----

volume of wastewater treated. Reverse osmosis simply concentrates materials in a dilute stream.

Zinc. Waste concentrations of zinc range from 1 to 1,000 mg/l in various waste streams described in the literature, but average values fall between 1 and 100 mg/l as shown in table VII-18. Table VII-19 summarizes published precipitation treatment results. As with nickel, cyanide forms a more soluble complex ion with zinc; therefore, cyanide treatement may be required before precipitation of zinc.

A treatment combining hydroxide and sulfide precipitation of heavy metals, known as the "Sulfex" process, has reported effective removal of zinc, chromium, and other trace metals. The Sulfex process has been used to treat water rinses following carburetor-casting treatment tanks in an automotive plant in Paris, Tennessee. The waste stream in this plant has a zinc concentration of 34 mg/l. Treatment has resulted in a filtered effluent concentration of less than 0.05 mg/l of zinc (47).

Copper. Primary sources of copper in industrial waste streams are metal process pickling and plating baths. For a given bath, the rinse water concentration will be a function of many factors, such as drainage time over the bath, shape of the parts, surface area of the parts, and the rate of rinse water flow. Untreated process waste water concentrations of copper typical of plating and metal processing operations are summarized in table VII-20.

As with most heavy metal wastes, treatment processes for removal of copper may be of a destructive nature, involving precipitation and disposal of resulting solids, or of a recovery nature, e.g., ion exchange, evaporation, and electrolysis. Ion exchange or activated carbon are appropriate treatment methods for wastewaters containing copper at concentrations less than 200 mg/l; precipitation is applicable for copper levels of 1.0 to 1,000 mg/l, and electrolytic recovery is advantageous for copper treatment at concentrations above 10,000 mg/l (45).

Generally, hydroxide precipitation is accomplished by lime addition to an acidic wastewater. The theoretical solubility limit of the metal ion is approximately 0.0004 mg/l at a pH of approximately 9.0 (46). Theoretical levels are seldom achieved due to colloidal precipitates, slow reaction rates, pH fluctuations, and the influence of other ions. Reported treatment levels achieved by full-scale industrial treatment operations are presented in table VII-21.

Selenium. Industries which use selenium include paint, pigment and dye producers, electronics, glass manufacturers, and insecticide industries. Selenium is similar to arsenic in several ways. For example, the two predominant oxidation states in water are Selenium IV (selenite) and Selenium VI (selenate) and selenium appears in the anion form and thus has acid characteristics. Very little information is available on levels of selenium in industrial wastewaters or treatment methods for selenium wastes.

Table V-18

CONCENTRATIONS OF ZINC IN PROCESS WASTEWATERS (45)

(mg/l)

Industrial Process	Zinc Concentration Range	Zinc Concentration Average
Metal Processing		
Bright dip wastes	0.2-37.0	
Bright mill wastes	40-1,463	
Brass mill wastes	8-10	
Pickle bath	4.3-41.4	
Pickle bath	0.5-37	
Pickle bath	20-35	
Aqua fortis and CN dip	10-15	
Wire mill pickle	36-374	
Plating		
General	2.4-13.8	8.2
General	55-120	
General	15-20	15
General	5-10	
Zinc	20-30	
Zinc	70-150	
Zinc	70-350	
Brass	11-55	
Brass	10-60	
General	7.0-215	46.3
Plating on zinc castings	3-8	
Galvanizing of cold rolled steel	2-88	
Silver Plating		
Silver bearing wastes	0-25	9
Acid waste	5-220	65
Alkaline	0.5-5.1	2.2
Rayon Wastes		
General	250-1000	
General	20	
General	20-120	

Table VII-19

SUMMARY OF PRECIPITATION TREATMENT RESULTS FOR ZINC (45, 47)

Source	Zinc (mg/l)		Percent Removal	Comment
	Initial	Final		
Zinc Plating	----	0.2-0.5	----	----
General Plating	18.4	2.0	89	
General Plating	----	0-6	----	Sand Filtration
General Plating	55-120	≤1.0	99	
Vulcanized Fiber	100-300	≤1.0	99	
Brass Wire Mill	36-374	0.08-1.60	99	Integrated Treatment for Copper Recovery
Tableware Plant	16.1	0.02-0.23	99	Sand Filtration
Viscose Rayon	20-120	0.88-1.5	----	
Viscose Rayon	70	3-5	93-96	
Viscose Rayon	20	1.0	95	
Metal Fabrication	----	0.5-1.2 0.1-0.5		(1) Sedimentation (2) Sand Filtration
Automotive Industry (Sulfex Process)	34	0.05	99	

Table VII-20

COPPER CONCENTRATIONS IN WASTEWATER FROM METAL PLATING AND PROCESSING OPERATIONS

(mg/l)

Process	Copper Concentration
Plating Rinse	20-120
Plating Rinse	0-7.9
Plating Rinse	20 (ave.)
Plating Rinse	5.2-41
Plating	6.4-88
Plating	2.0-36.0
Plating	20-30
Plating	10-15
Plating	3-8
Plating	11.4
Appliance Manufacturing	
Spent Acids	0.6-11.0
Alkaline Wastes	0-1.0
Automobile Heater Production	24-33 (28 ave.)
Silver Plating	
Silver Bearing	3-900 (12 ave.)
Acid Wastes	30-590 (135 ave.)
Alkaline Wastes	3.2-19 (6.1 ave.)
Brass Plating	
Pickling Bath Wastes	4.0-23
Bright Dip Wastes	7.0-44
Plating Wastes	2.8-7.8 (4.5 ave.)
Pickling Wastes	0.4-2.2 (1.0 ave.)
Brass Dip	2-6
Brass Mill Rinse	4.4-8.5
Brass Mill RInse	
Tube Mill	74
Rod and Wire Mill	888
Brass Mill Bichromate Pickle	
Tube Mill	13.1
Rod and Wire Mill	27.4
Rolling Mill	12.2
Copper Rinse	13-74
Brass Mill RInse	4.5

Table VII-20 (Continued)

COPPER CONCENTRATIONS IN WASTEWATER FROM METAL PLATING AND PROCESSING OPERATIONS

(mg/l)

Process	Copper Concentration
Brass and Copper Wire Mill	72-124
Brass and Copper Pickle	60-9
Brass and Copper Bright Dip	20-35
Copper Mill Rinse	19-74
Copper Tube Mill	70 (ave.)
Copper Wire Mill	800 (ave.)
Copper Ore Extraction	0.28-0.33
Gold Ore Extraction	20
Acid Mine Drainage	3.2
Acid Mine Drainage	3.9
Acid Mine Drainage	0.12
Acid Mine Drainage	51.6-128.0

Table VII-21

COPPER REMOVAL BY FULL-SCALE INDUSTRIAL WASTEWATER TREATMENT SYSTEMS (45)

Source and Treatment	Initial Copper conc. (mg/l)	Final Copper conc. (mg/l)	Removal Efficiency (%)
Metal Processing (Lime)	204-385	0.5	98.7-99.8
Nonferrous Metal Processing (Lime)	-	0.2-2.3 (prior to sand filtration)	-
Metal Processing (Lime)	-	1.4-7.8 (prior to sand filtration) 0.0-0.5 (after sand filtration)	-
Electroplating (caustic, Soda Ash + Hydrazine)	6.0-15.5	0.09-0.25 (sol.) 0.30-0.45 (tot.)	-
Machine Plating (Lime + coagulant)	-	2.2	-
Metal Finishing (Lime)	-	0-12 (ave. 0.19)	-
Brass Mill (Lime)	10-20	1-2	-
Plating	-	0.02-0.2	-
Plating (CN oxidation, Cr reduction, neutralization)	11.4	2.0	82.5
Wood Preserving (Lime)	0.25-1.1 (range)	0.1-0.35	-
Brass Mill (Hydrazine + NaOH)	75-124	0.25-0.85	-
Silver Plating (CN oxidation, Lime, Fe Cl3	30 (ave.)	0.16-0.3 (with sand filtration)	99-99.5

Secondary municipal sewage treatment plants with 2 to 9 ug/l of selenium in the effluent have been reported (45). A tertiary sequence of treatment which included lime treatment to pH 11, sedimentation, mixed-media filtration, activated carbon adsorption and chlorination yielded selenium removals of 0 to 89 percent. In another study (45), various advanced treatments were tested for a sewage treatment plant effluent with a selenium concentration of 2.3 ug/l. The investigators concluded that efficient removal (99 percent) could be achieved using a strong acid-weak base ion exchange system (45).

Jar tests and pilot plant tests conducted by WSRD on the removal of selenium from ground and surface waters by conventional coagulation showed that selenium removal is dependent on the oxidation state, initial concentration of selenium, pH, and types and doses of coagulation (44). Removals range from 0 to 81 percent using ferric sulfate and alum coagulants. In general, ferric sulfate was more efficient than alum in removing Selenium IV. Both ferric sulfate and alum yielded removals of 11 percent or less for Selenium VI. Initial selenium concentrations ranged from 0.03 to 0.10 mg/l. With dual media and granular activated carbon filters, removals as high as 80 percent were obtained for Selenium IV. WRDS also conducted pilot plant studies on lime-softening treatments for selenium removal. The results indicate that this is not an effective treatment for selenium removal (44). WSRD conducted studies which confirmed removals of greater than 99 percent using a cation-anion exchange system in series. Research on both laboratory and pilot plant scale is needed before feasibility of this treatment technique can be determined (44).

Ash Pond Overflows. The removal efficiencies which have been presented for arsenic, nickel, zinc, selenium and copper must be viewed with caution regarding application of removal efficiencies to fly ash and bottom ash pond discharges. Table VII-22 shows a comparison of the range of initial concentrations associated with the removal efficiencies which have been presented and the average concentrations of trace metals in fly ash and bottom ash pond discharges. The average concentrations in fly ash and bottom ash ponds are much lower than the ranges of initial concentrations contained in the literature; thus, the removal efficiencies do not necessarily reflect the efficiencies of such treatments for removal of trace metals in the ash ponds of steam electric powerplants. The final effluent concentration, however, would probably be lower for a powerplant because of the low initial concentration.

Bench scale studies of various removal technologies for treatment of ash pond effluents from steam electric powerplants have been conducted (48). Results of chemical precipitation treatments of the ash pond effluents from three powerplants located in Wyoming, Florida, and Upper Appalachia are shown in tables VII-23 and VII-24 for lime and lime and ferric sulfate addition, respectively. Arsenic removal appears to be reasonably good, ranging from 67 to less than 99 percent. Copper removals are variable, ranging from 31 to 80 percent. The efficiency of nickel removal is also uncertain. Selenium removal is, in general, fairly poor. This is consistent with other studies

Table VII-22

COMPARISON OF INITIAL TRACE METAL CONCENTRATIONS CITED IN STUDIES REPORTED IN THE LITERATURE AND TRACE METAL CONCENTRATIONS IN ASH POND DISCHARGES

(ppm)

Metal	Initial Concentrations Treated	Average Bottom Ash Concentrations	Average Fly Ash Concentrations
As	0.200 to 3.00	0.022	0.055
Ni	>21	0.079	0.224
Zn	18 to 374	0.020	0.034
Cu	0.25 to 385	0.012	0.003
Se	0.01 to 0.08	0.004	0.008

Table VII-23

TRACE METAL REMOVAL EFFICIENCIES FOR LIME PRECIPITATION TREATMENT OF ASH POND EFFLUENTS (48)

	Inlet (ppb)	Outlet (ppb)	Removal Efficiency %
Arsenic			
Wyoming	<1	1	DL
Florida	9	1	89
Appalachia	74	1	>99
Copper			
Wyoming	80	23	71
Florida	14	10	29
Appalachia	26	12	54
Nickel			
Wyoming	9.5	0.5	<95
Florida	5.5	6.0	OGTI
Appalachia	2.5	2.2	12
Selenium			
Wyoming	3	3	DL
Florida	8	8	NR
Appalachia	42	52	OGTI
Zinc			
Wyoming	300	31	90
Florida	7	2	57
Appalachia	11	<2	>82

KEY: DL - Concentrations of both inlet and outlet are below the detection limit.
OGTI - Outlet concentrations greater than inlet.
NR - No removal.

Table VII-24

TRACE METAL REMOVAL EFFICIENCIES FOR LIME PLUS FERRIC SULFATE PRECIPITATION TREATMENT OF ASH POND EFFLUENTS (48)

	Inlet (ppb)	Outlet (ppb)	Removal Efficiency %
Arsenic			
Wyoming	<1	<1	DL
Florida	9	3	67
Appalachia	74	<1	>99
Copper			
Wyoming	80	23	80
Florida	14	7	50
Appalachia	26	18	31
Nickel			
Wyoming	9.5	10.5	>95
Florida	5.5	9.0	OGTI
Appalachia	2.5	2.0	20
Selenium			
Wyoming	3	3	DL
Florida	8	7	12
Appalachia	42	32	24
Zinc			
Wyoming	300	25	92
Florida	7	6	14
Appalachia	11	<2	>82

KEY: DL - Concentrations of both inlet and outlet are below the detection limit.
OGTI - Outlet concentrations greater than inlet.
NR - No removal.

cited earlier on removal of selenium by chemical precipitation. The efficiency of zinc removal varies significantly from 14 to 92 percent. Though this study may indicate that chemical precipitation has potential for effective removal of some trace metals from ash ponds effluents, other studies are necessary to confirm these results.

Ash/Sludge Disposal. The two primary methods of ash disposal are landfill and utilization. Only a few plants presently sell or use fly ash. Ash which has been collected dry or has been dewatered is disposed of by landfill. Figure VII-39 illustrates some common landfill methods. Equipment requirements include closed trucks, graders, and bulldozers. Disposal of dry fly ash poses some fugitive dust problems. Closed trucks are used to prevent fugitive dust emissions enroute to the landfill site. At the site, the ash should be wetted down after application to the landfill.

Bottom Ash

The technologies applicable to bottom ash handling systems are:

1. dry bottom ash handling,

1. Hydrobin/dewatering bin systems, and

3. ponding with recycle.

Dry Systems

Dry handling of bottom ash is generally typical of stoker-fired boilers. This method is used by 19 percent of those plants which reported a bottom ash system type in the 308 survey (including all types of plants). Stoker-fired boilers are generally used in relatively small capacity installations where small amounts of bottom ash are handled. Since this technology represents a small and more obsolete sector of the industry, it is not addressed in further detail in this section.

Complete Recycle Systems

The term "complete recycle" describes a system which returns all of the ash sluice water to the ash collecting hoppers for recurrent use in sluicing. The key concept of complete recycle is that there is no continuous discharge of sluice water from the system. Virtually no system is zero discharge from the standpoint of containing all ash handling water onsite because ash-laden water does leave the facility in a variety of ways. Water is occluded with the ash when trucked away to disposal. Under upset conditions, it is often necessary to discharge water. In some cases, small amounts of water from the ash handling system are needed elsewhere in the plant, typically for wetting fly ash handling trucks to prevent blowing of dry fly ash and for servicing the silo unloaders. Makeup water is required to maintain a steady water balance despite these inherent losses in the

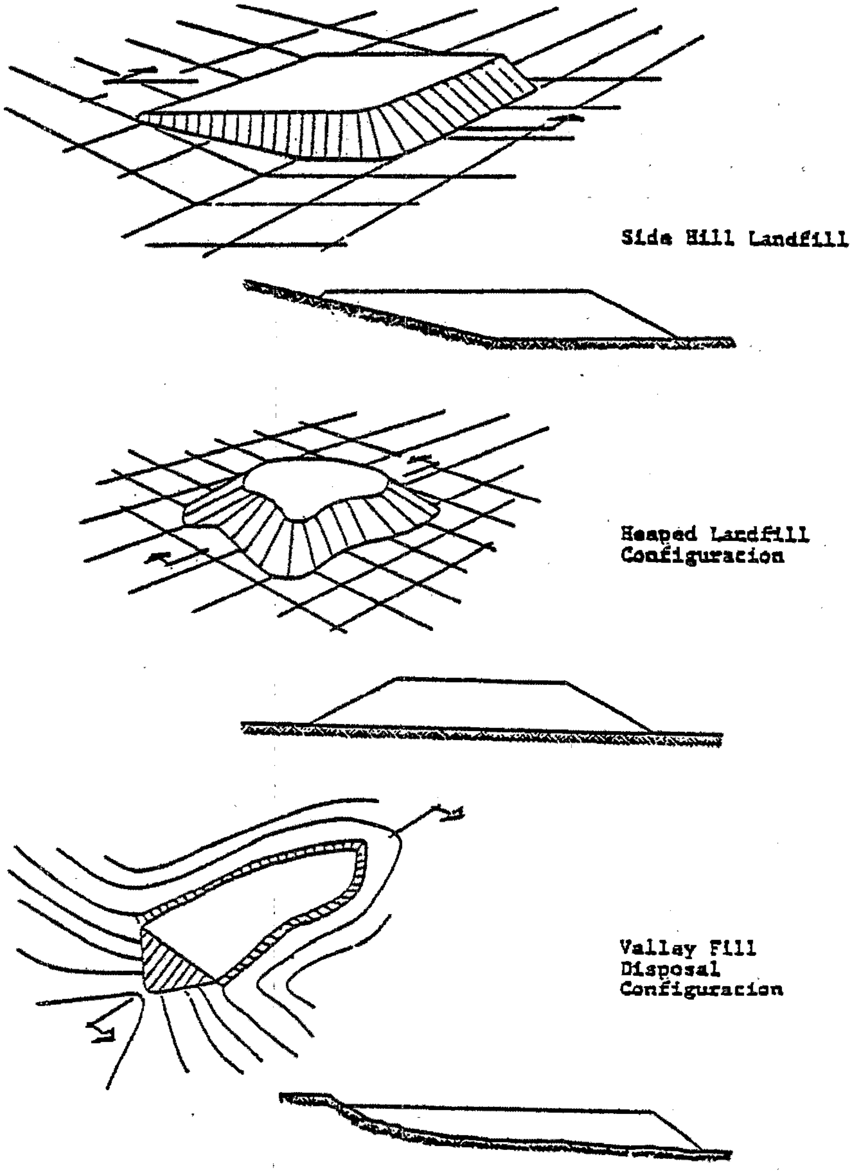

Side Hill Landfill
Heaped Landfill Configuration
Valley Fill Disposal Configuration

Figure VII-39

LANDFILL METHODS

system. The magnitude of the makeup water requirement depends upon the major equipment in the ash handling system.

Technology Descriptions.

Dewatering/Hydrobin System (36). The various stages of a closed-loop recirculating system appear in figure VII-40. For the sake of clarity, some details have been omitted. Initially, as illustrated in figure VII-40a, the ash hopper is filled to its overflow line, and one dewatering bin (bin A) is partially filled with water. Enough water remains in the storage tank to start operating the system after the ash hopper is filled with ashes. In the next stage, illustrated in figure VII-40b, the ash hopper has been filled with ashes, and the water displaced by them has been pumped into the settling tank and overflowed into the storage tank. In the next step, shown in figure VII-40c, ash hopper cleaning is in progress in the right hand chamber. Ashes are pumped to the Dewatering Bin A. As ash-water slurry enters the dewatering bin, an equal amount of water overflows to the settling tank and then to the storage tank. In figure VII-40d, the ash hopper has been completely emptied. All of the water that had been in the ash hopper is now in the storage tank. The water in the storage tank is used to refill the ash hopper as shown in figure VII-40f. The water in the ash hopper is then available for filling Dewatering Bin B as shown in figure VII-40g. The water volume in the settling tank remains constant while the volume in all other vessels varies during different phases of operation.

Outside makeup water is necessary to restore the water lost with the bottom ash discharged from the dewatering bins as well as water lost through evaporation from the bottom ash hopper. Makeup usually is added at the storage tank. An emergency bypass can be installed between the settling tank and the storage tank to provide needed water in the event of temporary failure of outside makeup.

In most cases, a closed-loop recirculating system shows a marked change in the pH of the recirculated water. This ph shift is tempered by the addition of makeup water if it is added in sufficient quantity and is of good quality. A monitoring system and chemical additives can maintain recirculated water at as neutral a level as possible in order to keep pipe scaling or corrosion to a minimum.

Cases where pH adjustment is not sufficient for scale prevention, such as very reactive bottom ash or poor intake water quality, may require side stream lime/soda ash treatment. The equipment for slip stream softening has been described in the section concerning physical/chemical treatment of ash pond overflows from wet once-through fly ash handling systems. The magnitude of the flow rate of the slip stream is estimated to be about 10 percent of the total sluice stream. The use of slip stream softening in a dewatering bin system would create an additional solid waste stream as well as an additional water loss source which would require more makeup water. Slip stream softening in a dewatering/hydrobin system is not a proven technology based on data from the 308 survey.

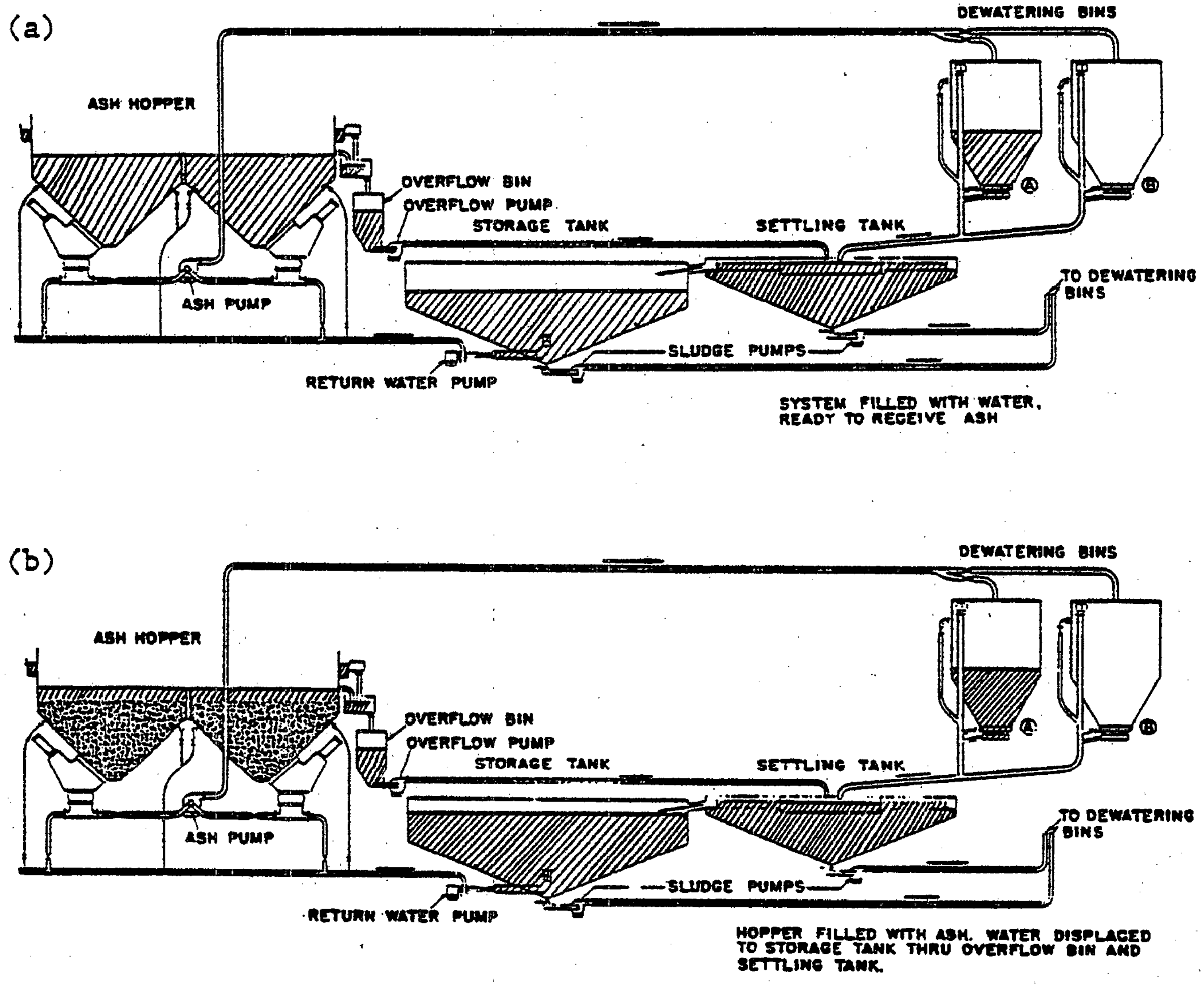
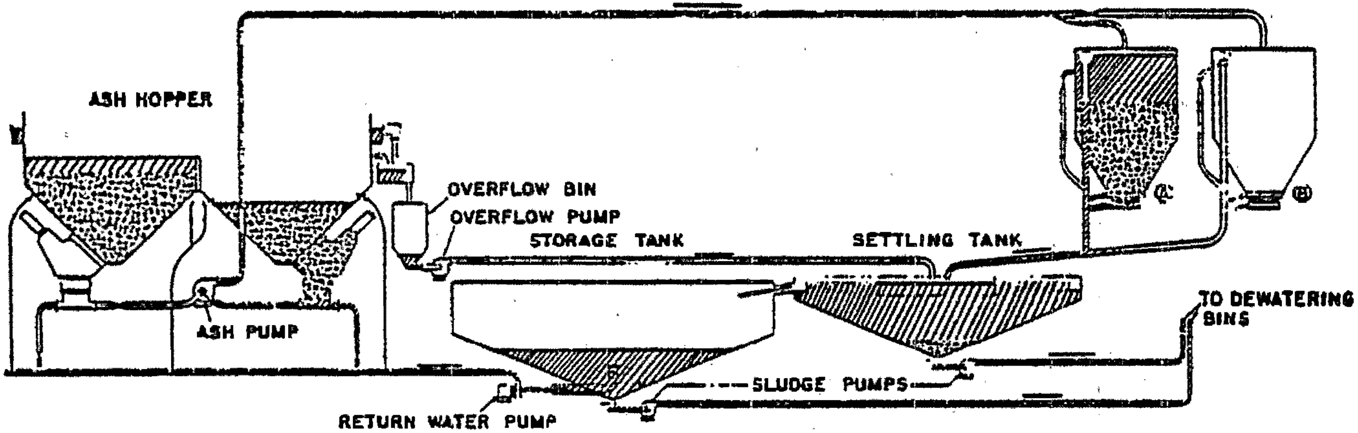

(a)
DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
TO DEWATERING BINS
ASH PUMP
SLUDGE PUMPS
RETURN WATER PUMP
SYSTEM FILLED WITH WATER, READY TO RECEIVE ASH
(b)
DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
TO DEWATERING BINS
ASH PUMP
SLUDGE PUMPS
RETURN WATER PUMP
HOPPER FILLED WITH ASH, WATER DISPLACED TO STORAGE TANK THRU OVERFLOW BIN AND SETTLING TANK.

Figure VII-40

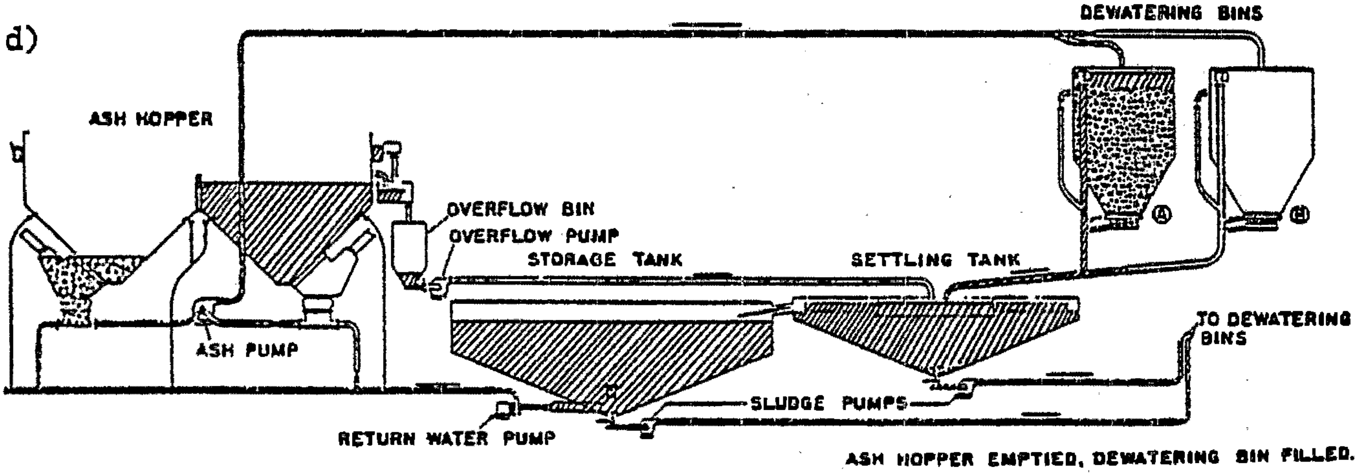
VARIOUS STAGES OF A CLOSED-LOOP RECIRCULATING SYSTEM (36)

(c)


DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
ASH PUMP
TO DEWATERING BINS
SLUDGE PUMPS
RETURN WATER PUMP

ASH HOPPER BEING EMPTIED. DEWATERING BIN BEING FILLED, OVERFLOW TO SETTLING TANK.

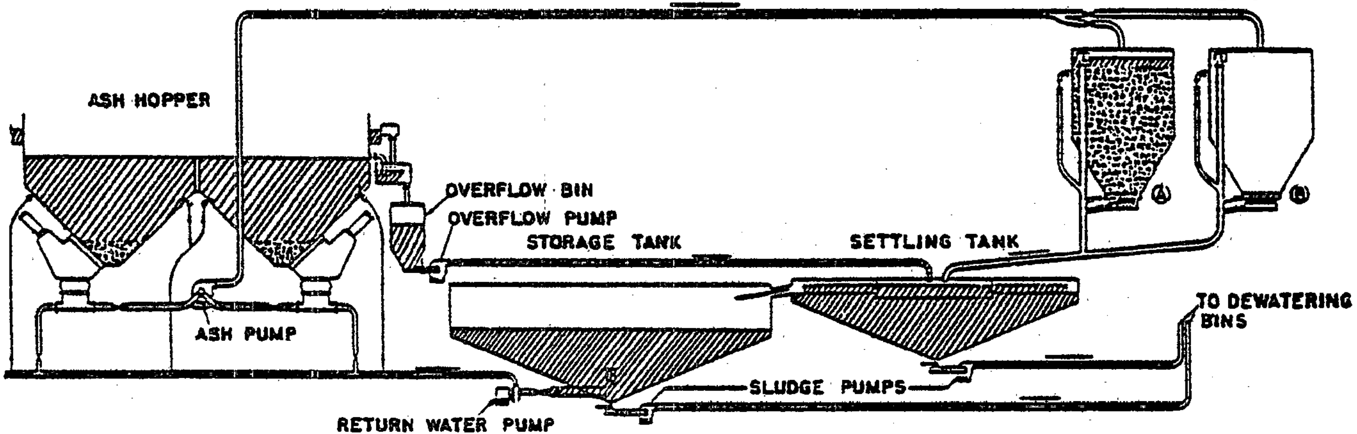
(d)


DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
ASH PUMP
TO DEWATERING BINS
SLUDGE PUMPS
RETURN WATER PUMP

ASH HOPPER EMPTIED, DEWATERING BIN FILLED.

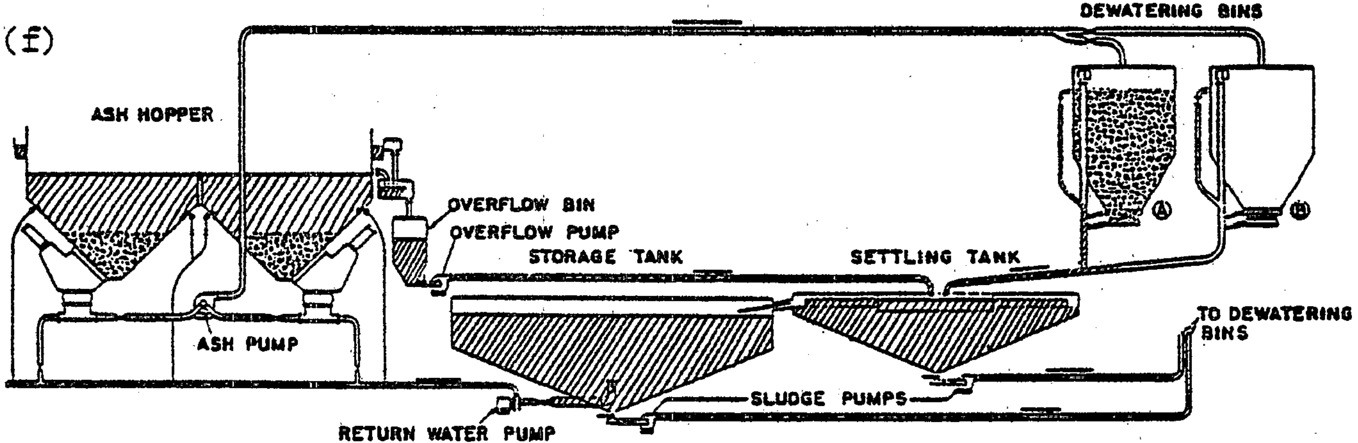
Figure VII-40 (Continued)
VARIOUS STAGES OF A CLOSED-LOOP RECIRCULATING SYSTEM (36)

(e)


DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
ASH PUMP
TO DEWATERING BINS
SLUDGE PUMPS
RETURN WATER PUMP

ASH HOPPER REFILLED WITH WATER.

(f)


DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
ASH PUMP
TO DEWATERING BINS
SLUDGE PUMPS
RETURN WATER PUMP

DEWATERING BIN BEING DRAINED.

Figure VII-40 (Continued)
VARIOUS STAGES OF A CLOSED-LOOP RECIRCULATING SYSTEM (36)

(g)

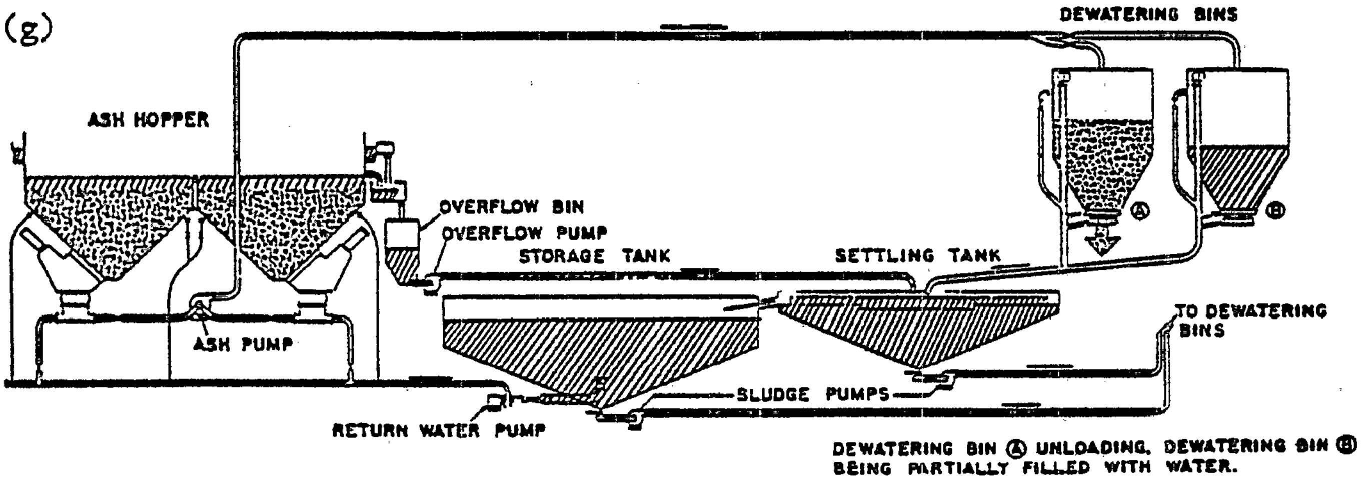

DEWATERING BINS
ASH HOPPER
OVERFLOW BIN
OVERFLOW PUMP
STORAGE TANK
SETTLING TANK
Ⓐ
Ⓑ
ASH PUMP
TO DEWATERING BINS
SLUDGE PUMPS
RETURN WATER PUMP
DEWATERING BIN Ⓐ UNLOADING, DEWATERING BIN Ⓑ BEING PARTIALLY FILLED WITH WATER.

Figure VII-40 (Continued)
VARIOUS STAGES OF A CLOSED-LOOP RECIRCULATING SYSTEM (36)

Bottom ash obtained from dewatering bins is considered "commercially dry" by vendors of this equipment (36, 39), i.e., on the order of 20 percent moisture. This degree of moisture can vary widely depending on the installation as well as within a particular plant. The ash is wet enough for transport to a landfill site in an open truck without creating a fugitive dust problem, and at the landfill site, there is no need to wet the ash down. Some dust problems may occur with certain western coal ashes since these tend to contain relatively more fines than eastern coal ashes (39).

A dewatering/hydrobin system which contains a slip stream softening system produces a sludge waste stream which requires disposal. This waste is produced at a much lower rate than is the bottom ash and has a higher moisture content.

Ponding System. Approximately 81 percent of all plants which replied in the 308 survey designated ponding as their bottom ash handling method. Of these, approximately 9 percent designated either complete or partial recycle.

A ponding recycle system for bottom ash is illustrated in figure VII-41. The ash or slag collected in the bottom ash hopper which is filled with water is ground down to a sluiceable size range by clinker grinders at the bottom of the hopper. Depending on the size of the boiler, the bottom ash hopper may have two or three "pantlegs," or discharge points. At each pantleg there may be one or two clinker grinders. Larger facilities usually have three pantlegs and two clinker grinders at each pantleg (39). Smaller facilities have two pantlegs and one clinker grinder at each leg. Double roll clinker grinders can generally handle from 75 to 150 tons per hour of ash with drives from 5 hp to 25 hp depending on the material to be crushed and required system capacity. A smaller grinder that can handle 20 tons per hour or less uses a single roll with a stationary breaker plate.

After being crushed, the ash is fed into an adopter or sump from which it is pumped by one of two types of pumping devices, a centrifugal pump or a jet pump. Pumps and piping have already been discussed in the subsection on partial recirculating fly ash systems.

A series of ponds are usually used for bottom ash settling. A primary pond accumulates most of the sluiced bottom ash. The sluice water then flows by gravity to a secondary settling pond. Overflow from the secondary pond goes to a final or clear pond which is used as a holding basin for the recirculating water. Pond sizes cover a wide range depending on the plant size, the amount of bottom ash produced (boiler type), pond depth, required holding time (which is a function of the solids settling rate), and the amount of land available. Typically, the primary and secondary ponds are dual systems so that dredging does not interfere with operation. For instance, a plant may have two primary and secondary ponds. One primary and one secondary are dredged annually to remove the settled solids while the other two ponds are in operation.

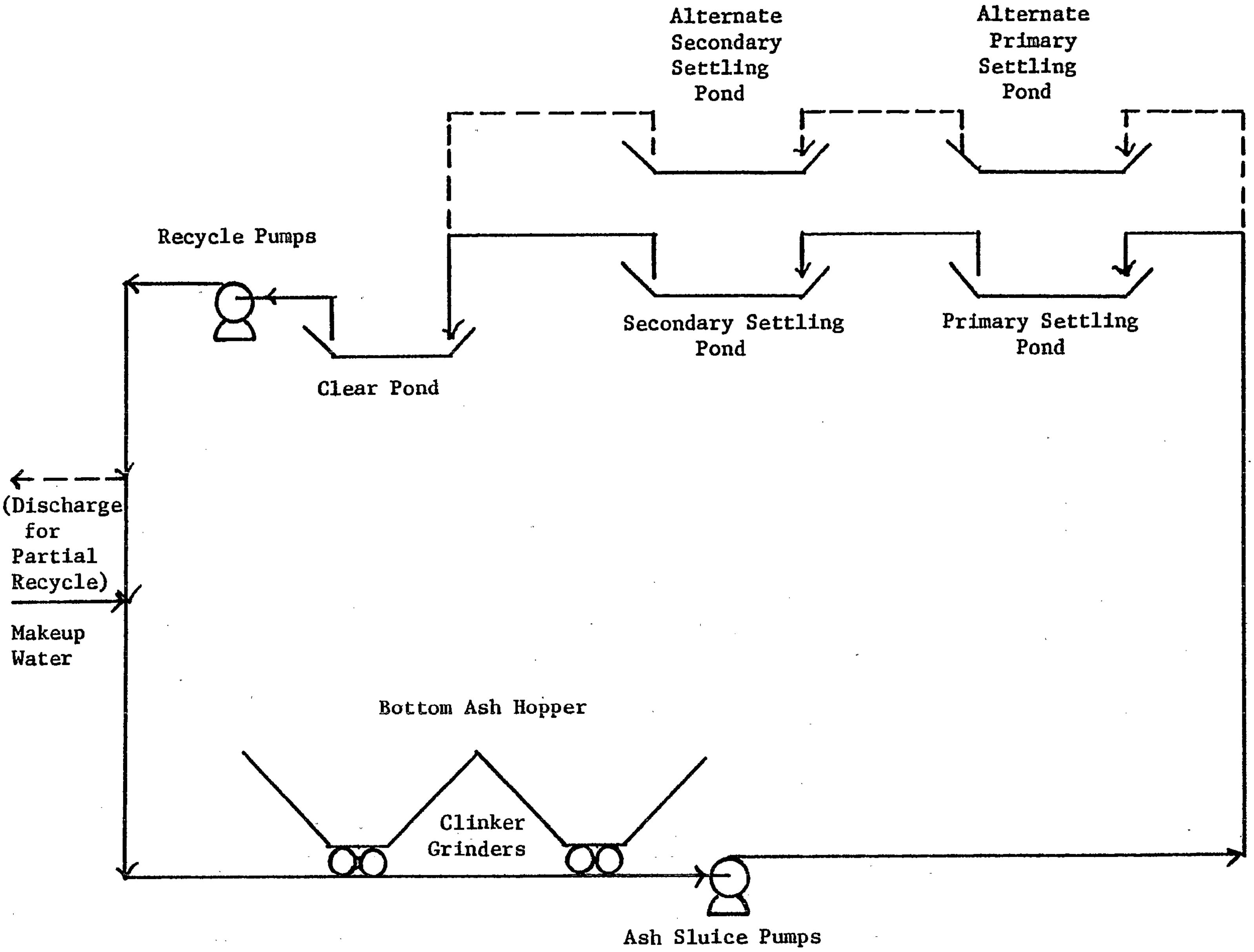

Alternate Secondary Settling Pond
Alternate Primary Settling Pond
Recycle Pumps
Secondary Settling Pond
Primary Settling Pond
Clear Pond
(Discharge for Partial Recycle)
Makeup Water
Bottom Ash Hopper
Clinker Grinders
Ash Sluice Pumps

Figure VII-41

PONDING RECYCLE SYSTEM FOR BOTTOM ASH

Facilities may be made available to provide for a discharge of sluice water from the recycle line. A makeup water stream will be necessary due to water losses inherent in the system. The most significant water losses occur in percolation through the floor of unlined ponds and evaporation of pond water. A pond system maintained at a steady-state water balance without discharging is considered a zero discharge or complete recycle system. A partial recycle system maintains a discharge either on a continuous basis or for upset conditions.

Bottom ash recovered from ponds by dredging does not create fugitive dust problems because of the high moisture content of the ash. Disposal of bottom ash may be achieved by any of the conventional landfill methods discussed in the fly ash subsection.

Evaporation Ponds. In cases where pH adjustment can not adequately prevent scale, an alternative to slip stream softening is the release of some of the ash sluice water as a blowdown stream. In cases where it is difficult to maintain a steady water balance in a complete recycle system, occasional discharge of ash sluice water may be necessary. The use of evaporation ponds to contain blowdown streams from dewatering bin systems is an option for achieving zero discharge under these conditions. This option has been successfully exercised in the western part of the United States where high net evaporation rates are indigenous. Two of the plants visited attained zero discharge by using a blowdown to evaporation ponds from dewatering bin systems.

Retrofitting. The primary reasons for retrofitting complete recycle systems are:

1. A shortage of water requiring minimal consumption,
2. State or local regulations governing a reduction in wastewater pollutants, and
3. A market for dewatered slag.

Some of the piping from the old system is reusable in the retrofitted system, although difficulties may be encountered in rerouting old pipe. Of course, difficulty may be encountered in integrating any other system discharge with the bottom ash recycle loop, e.g., sump discharge and cooling tower blowdown. Plant downtime would be required for the hook-up of the retrofitted dewatering bin system, resulting in a temporary reduction in generating capacity. In addition, some downtime may occur during the debugging period. For some plants, debugging may last up to a year. The land required to retrofit a dewatering bin system is:

- Approximately 1 acre to contain the dewatering bins, settling tank, surge tank, and pump houses; and
- Landfill area for bottom ash disposal.

A plant that used a pond system prior to the retrofit of the dewatering bin system probably would have land available for disposal of the dewatered bottom ash.

Utilization of Complete Recycle Systems. Data from the 308 survey provided a list of plants which reported wet recirculating bottom ash handling systems and zero discharge of ash transport water. EPA teleponed each of these 14 plants to confirm the data submitted on the 1976 data form. The results of the telephone contacts appear in table VII-25. Specific details of plant designs are discussed below.

This information has not been positively confirmed for all 14 plants. The only method of positive confirmation is site inspection but time and budget constraints precluded visitation of all 14 plants. Four of the plants were visited.

Plants 4813, 3203, 1811 and 0822, handle and dispose of bottom ash completely separately from fly ash. The plants employ dry fly ash handling and complete recirculation of bottom ash transport water. The plants are located in Texas, Indiana, Nevada, and Colorado. The facilities in Nevada and Colorado make use of high evaporation rates in those locations to achieve zero discharge while allowing for some blowdown from the systems. The fuels burned at these plants include lignite and bituminous coals with the ash contents ranging from 9.7 percent to 11.5 percent. The boiler types include both pulverized coal boilers and cyclone boilers, giving a bottom ash to fly ash ratio from 20:80 to 90:10. These plants represent zero discharge designs; while the absolute number of plants identified as achieving zero discharge from this study is small, they do present a representative mix of location fuel type and boiler type.

Plants 4813, 3203, and 0822 use hydrobines or dewatering bins to separate the bottom ash particles from the sluice water. In each case, the sluice water overflows the weir at the top of the bin and gravity flows to a surge tank which supplies the suction side of the recycle or recirculation pumps. Makeup water to compensate for evaporation, water lost from pump seals, water lost from the ash hopper locks, water occluded with the bottom ash and other spills and leaks is added at some point in each system depending on the plant. Accurate control of makeup water is an important factor in achieving zero discharge. If the actual makeup rate exceeds the required makeup rate, a system upset occurs which causes discharge of ash transport water. Such upsets do occur in most systems from time to time, but do not constitute normal operating procedure. Plant 4813 has settling ponds backing up the hydrobins. Bottom ash can be sent to either system. One pond serves as a recycle tank from which recirculating sluice water is drawn.

Plant 1811 uses a ponding system to separate the bottom ash from the sluice water. Once side of the settling pond is wide and gradually inclined. The ash is sluiced to this open area where the heavy material forms a pile. The sluice water drains into a final settling

Table VII-25

DATA SUMMARY OF PLANTS REPORTING ZERO DISCHARGE OF BOTTOM ASH TRANSPORT WATER

Plant Code	Location	Fuel	Boiler Type	Ash Handling Systems	Comments
2903	Missouri	Bituminous (13.8% ash)	Pulverized-Dry Bottom	- Fly Ash can be either dry transported to silo (for sale) or or sluiced to pond - Bottom Ash is sluiced to pond and water is recycled	Not all sluice water is recycled some is discharged to a river
2705	Minnesota	Subbituminous (9% ash)	Pulverized-Dry Bottom	- Fly Ash removed in wet scrubber - Bottom Ash is sluiced to pond and some of sluice water is recycled	The Bottom Ash Sluice water not recycled serves as scrubber makeup
2413	Maryland	Bituminous (14.6% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash sluiced to hydrobins overflow to surge tank and recycled	Not all the sluice water is recycled some reaches central treatment plant
4813	Texas	Lignite (10.4% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash sluiced either to hydrobins or primary settling ponds all sluice water is recycled	Zero discharge of bottom ash sluice water

Table VII-25 (Continued)

DATA SUMMARY OF PLANTS REPORTING ZERO DISCHARGE OF BOTTOM ASH TRANSPORT WATER

Plant Code	Location	Fuel	Boiler Type	Ash Handling Systems	Comments
5102	Virginia	Bituminous (17.8% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash is sluiced to a pond and all pond water is recycled	Drains carrying discharges from ash hoppers and pumps go to central treat ment facility and are discharged
4229	Pennsylvania	Bituminous (11.5% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash is sluiced to a pond some of the water is recycled	Not a zero discharge facility
4230	Pennsylvania	Bituminous (10% ash)	Pulverized-Dry Bottom	- Wet Fly ash handling with recirculation of water - Bottom ash sluiced to a pond, some of the water is recylced	Not a zero discharge system facility, ash transport water goes to treatment facility
2901	Missouri	Subbituminous (25% ash)	Pulverized-Wet Bottom	- Fly ash is sluiced to settling pond water is recycled - Bottom ash is sluiced to settling pond and water is recycled	Combined ash pond, all water is recycled-zero discharge of ash transport water

Table VII-25 (Continued)

DATA SUMMARY OF PLANTS REPORTING ZERO DISCHARGE OF BOTTOM ASH TRANSPORT WATER

Plant Code	Location	Fuel	Boiler Type	Ash Handling Systems	Comments
3203	Nevada	Bituminous (9.69% ahs)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash is sluiced to dewatering bins and water is recycled	Blowdown from bottom ash sluicing system goes to evap. ponds
1811	Indiana	Bituminous (11.54% ash)	Cyclone-Wet Bottom	- Dry Fly ash handling - Bottom ash is sluiced to a pond, water is recycled recycled	Zero discharge design however blowdown is removed at times when water balance problems occur
1809	Indiana	Bituminous (13.72% ash)	Cyclone-Wet Bottom	- Fly ash is wet sluiced to ponds overflow goes to recycle - Bottom ash is wet sluiced to holding pond overflow to recycle	Recycle serves both fly ash and bottom ash sluicing operations, zero discharges except under upset conditions
3626	New York	Bituminous (17.7% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash wet sluiced to hydrobins, overflow to surge tank and recycled	Some water is discharged due to water balance problems

Table VII-25 (Continued)

DATA SUMMARY OF PLANTS REPORTING ZERO DISCHARGE OF BOTTOM ASH TRANSPORT WATER

Plant Code	Location	Fuel	Boiler Type	Ash Handling Systems	Comments
2415	Maryland	Bituminous (14.58% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash wet sluiced some of water is recycled	Not a zero discharge plant, sluiced water is treated prior to discharge
0822	Colorado	Bituminous (10.66% ash)	Pulverized-Dry Bottom	- Dry Fly ash handling - Bottom ash is wet sluiced to hydrobins and overflow goes to recycle basin	Blowdown from sluice system is sent to evaporation pond

pond at the base of the incline. The recirculation pumps draw suction from this pond. All system drains and leaks are sent to this pond.

Plants 2901 and 1809 sluice both fly ash and bottom ash. These two sluice waters are ponded prior to recycle. In both cases, the primary settling ponds for fly ash and bottom ash are separate ponds. The overflow from these ponds gravity flows to a final settling pond. Both plants are zero discharge designs. Only under upset conditions is ash handling water discharged. The plants are located in Missouri and Indiana and burn a subbituminous coal with 25 percent ash and a bituminous coal with 13.7 percent ash. Both plants have cyclone boilers which give a bottom ash to fly ash ratio of 90:10.

The remaining plants employ some continuous blowdown or discharge from the recirculating bottom ash sluicing systems. These plants have very low discharge rates but are not zero discharge facilities. Only one plant, 4429, was designed to be zero discharge but was unable to close the water balance due to problems in accurately monitoring the makeup water requirement. An additional plant, 2750, was not intended to be a closed-loop bottom ash system since the scrubber makeup is drawn from the recycle tank. If the scrubber loop can be operated in a closed-loop or zero discharge mode, this plant could be considered a zero discharge facility from the standpoint of ash handling. It could not, however, be representative of achievable complete recycle technology for bottom ash handling.

Each plant contact was asked if any scaling or corrosion problems had resulted from the recirculation mode of operations. Only one plant, 2750, indicated that scaling in the recirculation line might be a problem. No such problems have been encountered however. The plants in the survey produce both alkaline ash and acid ash covering the range of chemical properties of ash handling waters.

Trip Reports. Four plants were visited to confirm the bottom ash handling practices as zero discharge. Only two of the four plants were true zero discharge plants: 3203 and 0822. In both cases a blowdown from the bottom ash sluicing systems (with dewatering bins) was observed; however, this blowdown was directed to evaporation ponds on plant property. The purpose of the blowdown was primarily to maintain a steady-state water balance. The remaining two plants, 1811 and 1809, were confirmed as having discharges and were considered partial recycle plants.

Abridged versions of the trip reports for these plants are contained in this subsection. A description of the bottom ash handling system, a discussion of retrofitting problems, a discussion of operating and maintenance problems, and a presentation of sampling and analysis work are provided for each plant.

Plant 3203. This plant is a 340-MW western bituminous coal- burning facility that uses a dewatering bin (United Conveyor Corporation) bottom ash sluice recycle system with a series of evaporation ponds. The plant fires a moderately low-sulfur coal (average 0.6 percent) with an average ash content of 12 percent and fluctuation to approximately 16 percent ash. The availability of the three boilers has historically averaged 86 percent annually. Water comes from two sources. During the summer, water is pumped from wells and during the winter, from a nearby river. The water is pumped to a reservoir for holding and then to the three cooling towers. Blowdown from the cooling towers accumulates in a storage tank. Water from this storage tank then feeds the three SO_2 scrubbers as well as the bottom ash sluicing system. The bottom ash storage tank receives water from the cooling tower blowdown storage tank and from the plant drain sump; the drain sump receives water from the area drains and boiler blowdown. A generalized flow diagram appears in figure VII-42, which shows the major equipment and associated typical flow rates.

The bottom ash sluicing system was designed and installed by United Conveyor Corporation. It was retrofitted to Units 1 and 2 and was installed along with Unit 3. The system was designed for 7 percent ash coal with capacity to handle a fourth unit, which was to be built at a later date. The bottom ash handling system is currently operating at a greater-than-rated capacity due to the higher-than-average ash coal being burned in the three units.

The general flow scheme for this bottom ash recycle system is shown in figure VII-43. The bottom ash handling system processes approximately 77 tons per day of bottom ash as well as 1 ton per day of economizer ash for all three units combined. The bottom ash is pumped from the hoppers to the dewatering bins for approximately 4 hours per day, the economizer ash for 1 hour each day. It takes approximately 6 hours to dewater the bottom ash in the bin to yield an ash moisture content of about 20 percent to 50 percent. Approximately one truckload of dewatered bottom ash is hauled to the onsite disposal area per day. The number of loads per month varies from 30 to 40. The disposal area is 1 mile from the plant. The hauling and placement of the ash is contracted to an outside firm.

The major equipment for the bottom ash recycle system was bought from and installed by United Conveyor Corporation. The dewatering bins are 30 feet in diameter, with 5,000 cubic feet per bin. Two bins are used: one dewaters ash, while the other fills with ash. The drained-off water from the bins flows by gravity to a settling tank of 50 feet in diameter and a capacity of 145,000 gallons. Sludge pumps are provided beneath the settling tank to pump any settled solids back into the top of the settling tank. Overflow from the settling tank drains into the surge (or storage) tank, which is of the same diameter and capacity as the settling tank. The surge tank is operated, however, at 19,108 cubic feet, or 135,000 gallons. Sludge pumps beneath the surge tank pump any settled solids back into the settling tank. From the surge tank, water is pumped back to the bottom ash hoppers for subsequent sluicing. A jet pump provides the pressure for transporting the ash to the dewatering bins. The length of pipe from the bottom ash hopper to the dewatering bin is approximately 500 feet for Unit 3 and 100 feet from Units 1 and 2. The pipe diameter for this system is typically 10 inches with a discharge pressure of 200

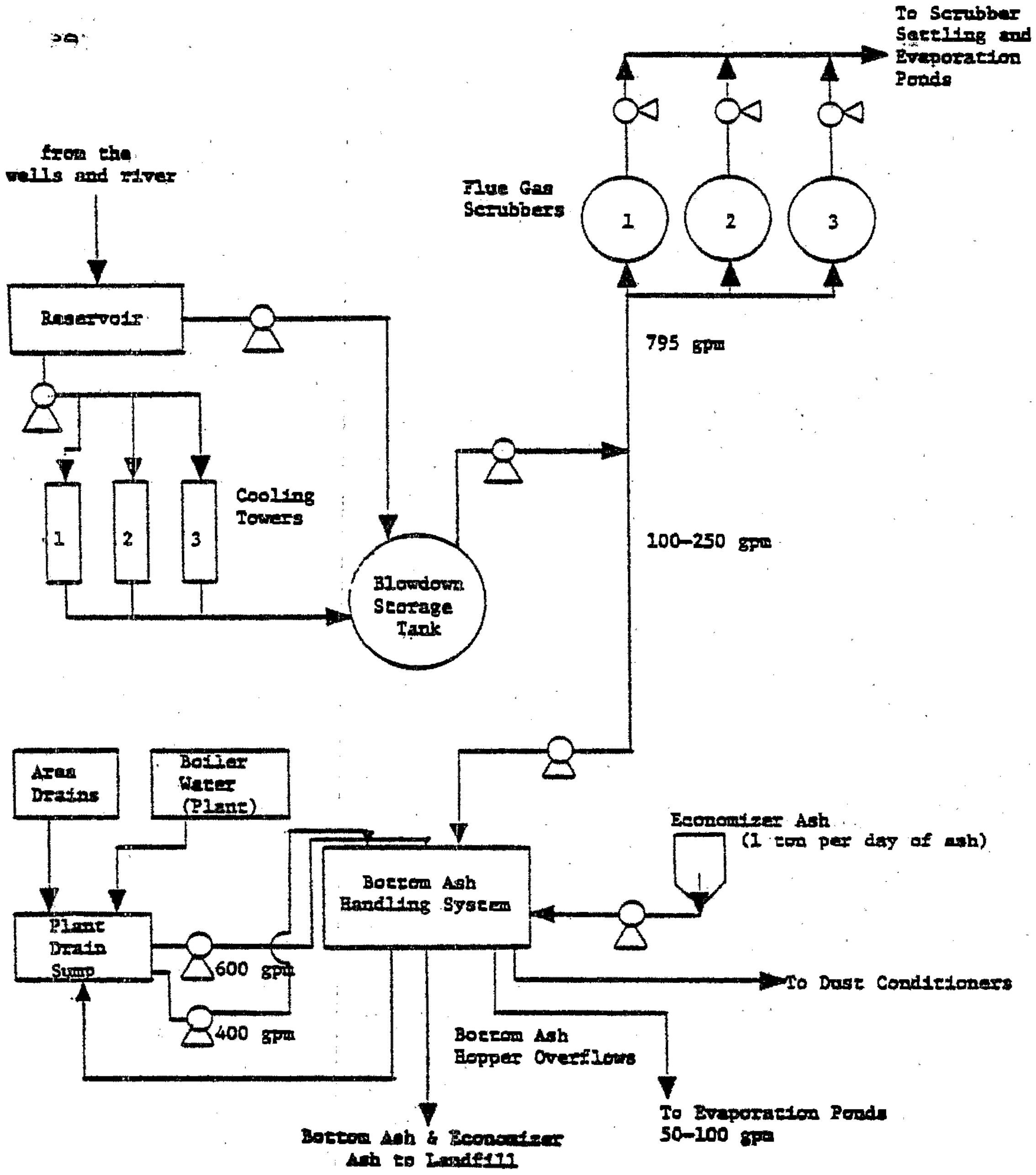

To Scrubber Settling and Evaporation Ponds
from the wells and river
Flue Gas Scrubbers
1
2
3
Reservoir
795 gpm
Cooling Towers
1
2
3
Blowdown Storage Tank
100-250 gpm
Area Drains
Boiler Water (Plant)
Economizer Ash (1 ton per day of ash)
Bottom Ash Handling System
Plant Drain Sump
600 gpm
400 gpm
To Dust Conditioners
Bottom Ash Hopper Overflows
To Evaporation Ponds 50-100 gpm
Bottom Ash & Economizer Ash to Landfill

Figure VII-42

WATER FLOW DIAGRAM FOR PLANT 3203

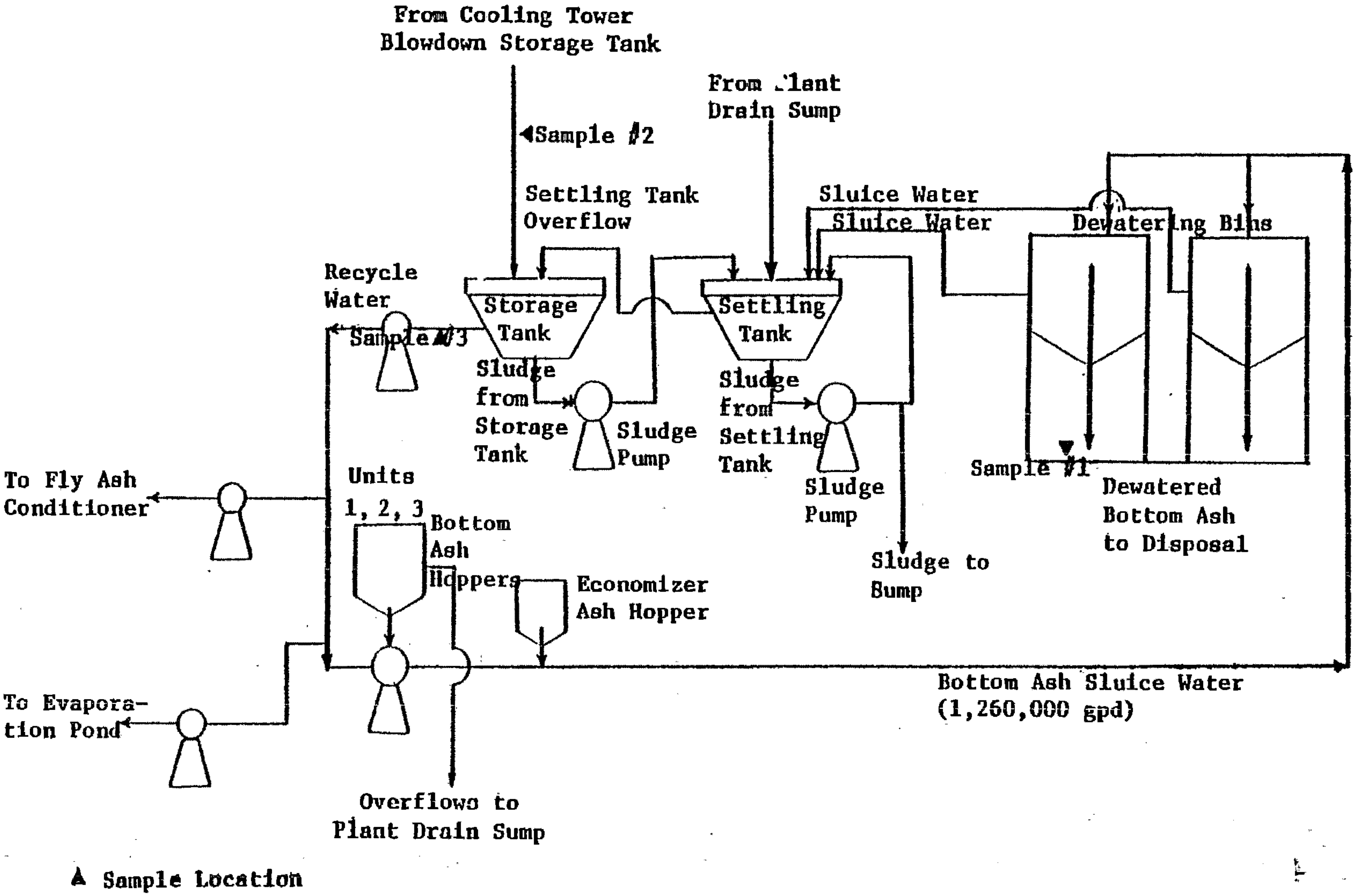

From Cooling Tower
Blowdown Storage Tank
Sample #2
From Plant
Drain Sump
Settling Tank
Overflow
Sluice Water
Sluice Water
Dewatering Bins
Recycle
Water
Sample #3
Storage
Tank
Settling
Tank
Sludge
from
Storage
Tank
Sludge
Pump
Sludge
from
Settling
Tank
Sludge
Pump
Sample #1
Dewatered
Bottom Ash
to Disposal
To Fly Ash
Conditioner
Units
1, 2, 3
Bottom
Ash
Hoppers
Economizer
Ash Hopper
Sludge to
Sump
Bottom Ash Sluice Water
(1,260,000 gpd)
To Evapora-
tion Pond
Overflows to
Plant Drain Sump
Sample Location

Figure VII-43

BOTTOM ASH RECYCLE SYSTEM AT PLANT 3203

psi. The land area devoted to the dewatering bins, settling tank, and surge tank is approximately one acre; this does not include the pump house or pipe rack. The bottom ash is trucked to a 200-acre, onsite landfill area. Side streams are taken from the bottom ash sluice lines which feed the fly ash dust conditioning nozzles and from a purge stream to the evaporator ponds. The purge flow rate is continuous and varies from approximately 50 to 100 gpm.

The maintenance of the sluicing system has been nominal since installation in 1975. No chemical testing for scaling species has been done and no scaling has been observed to the extent of producing a malfunction in equipment or line pluggage. Some minor corrosion on valves has occurred and some pump repair has been needed due to minor erosion.

There is a problem with solids plugging the bottom of the settling tank. This is due to several inherent design aspects of the system. The settling tank is not designed to remove large amounts of sludge. In this system, the plant drain sump discharges to the settling tank as well as the sludge from the surge tank. Adding to the problem is the fact that the system was designed to remove less ash than is currently being generated. Generation of fines is indigenous to western bituminous coal ash. These fines can plug the dewatering bin screens and overflow into the settling tank. A platform has been built over the settling tank to provide access for air lancing the solids in order to prevent sludge pump plugging. The settling tank sludge pumping capacity is to be doubled in the future to help reduce the load on the current pumps.

The entire bottom ash system requires two men per day for maintenance and one man per shift each day for operation of the system.

The motivation for retrofitting the bottom ash recycle system was a general water shortage problem associated with both wet once- through bottom ash and fly ash handling systems. At the time the bottom ash recycle system was installed, a pressure dry fly ash handling system and a third unit were also installed. Scaling problems tended to be more prevalent in the wet once-through system than in the current bottom ash sluice recycle system. Some of the wet once-through system piping was reused in the installation of the new bottom ash system. A 2-week outage for Units 1 and 2 occurred when the retrofit systems were installed and major pipe rerouting was done. It took approximately a year to debug the fly ash and bottom ash systems as well as the new Unit 3.

Samples were taken at three different locations in the bottom ash sluicing system. These locations are shown in the bottom ash sluicing system diagram in figure VII-43 and are described as follows:

1. A sample was taken of a stream of water leaking through the slide gate at the bottom of the dewatering bins,

2. A sample was taken of the recycle system makeup water from the cooling tower blowdown tank, and

3. A sample was taken at the recirculation pump which pumps the ash transport water back to the bottom ash hoppers.

These samples provide an indication of the trace elements, major species, and carbon dioxide content of transport streams before and after dewatering of the bottom ash and of the makeup water to the system. The trace elements which were quantified include silver, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, and zinc. Other metal elements (major species) were magnesium, calcium, and sodium. The non-metal major species quantified were phosphate, sulfate, chloride, silicate, and carbon dioxide. The results of the analyses are presented in tables VII-26 and VII-27.

Of the three samples taken, the cooling tower blowdown had the highest concentrations in arsenic, magnesium, sulfates, and silicates. The pH of this stream was 8.2, and the temperature was 96 F. Dilution of this stream in the surge tank with the plant drain sump effluent resulted in lower concentrations of these species. Species which had the highest concentrations at the recirculation pump, i.e., downstream from the surge tank, were phosphates, chlorides, carbon dioxide, zinc, and sodium. The pH of this stream was 8.2, and the temperature was 126 F. The third sample was taken from a leak beneath the dewatering bin during an ash dewatering mode of operation. The pH of this water was 10.4, and the temperature was ambient, 106 F. The significant species in this sample relative to the other two samples were copper, lead, and calcium.

On the basis of the sampling results and the subsequent analyses, EPA assessed the potential for precipitation of certain species by using an aqueous equilibrium computer program. The results from this assessment indicated that the calcium carbonate species has the greatest potential for precipitation in the leakage from the dewatering bin sample. The next greatest potential for the same species was in the cooling tower blowdown. The lowest potential was in the recycle stream prior to the recirculation pump. In this case, the maximum precipitation potential occurred in the stream in contact with the coal ash for the greatest period of time.

In conclusion, a closed-loop bottom ash system is feasible at Plant 7281 by using discharge to an evaporation pond. The technical problems associated with the equipment in the closed-loop system were of a reconciliable design nature. The only significant equipment problem exists because the settling tank was designed to handle all the overflow fines from the dewatering bins. More modern systems pipe these overflow fines back to dewatering bins. Chemically, there seemed to be no major cycling of trace elements and major species concentrations as a result of the closed-loop operation. It appears, however, that the concentration of copper increases as a consequence of sluice water being in contact with the coal ash. Contact with the

Table VII-26

TRACE ELEMENTS/PRIORITY POLLUTANTS[1] CONCENTRATIONS AT PLANT 3203

(ug/l)

	Cooling Tower Blowdown	Leakage from Dewatering Bin	Recirculation Pump
pH	8.20	10.40	8.20
Temp. (°F)	96	--	96
Silver	<0.1	<0.1	<0.1
Arsenic	71	4	26
Beryllium	<0.5[2]	<0.5	<0.5
Cadmium	<0.5	<0.5	<0.5
Chromium	15	24	19
Copper	21	49	5
Mercury	<2	<2	<2
Nickel	<0.5	<0.5	<0.5
Lead	<3	4	<3
Antimony	8	<1	5
Selenium	5	<2	<2
Thallium	<1	<1	<1
Zinc	160	40	40

---

[1] Two analyses were done for each sample species; the results are given as the average for each element.

[2] <.5 refers to the fact that the measured concentration was less than 0.5 g/l, which is the detection limit for this species.

NOTE: All concentrations reflect dissolved as opposed to total concentrations.

Table VII-27

MAJOR SPECIES CONCENTRATION[1] AT PLANT 3203

(mg/l)

	Cooling Tower Blowdown	Leakage from Dewatering Bin	Recirculation Pump
Calcium	395	505	310
Magnesium	190	1	105
Sodium	645	780	770
Phosphate[2]	0.40	0.06	2.30
Sulfate	2546	1773	1786
Chloride	394	601	622
Silicate	181	27	92
Carbonate	2520	60	2760

---

[1] Two analyses were done for each sample for Ca, Mg, Na; the results are given as an aveage of the two values.

[2] All species except Ca, Mg, Na, were analyzed only once; one number is reported for each sample species.

NOTE: All concentrations reflect dissolved as opposed to total concentrations.

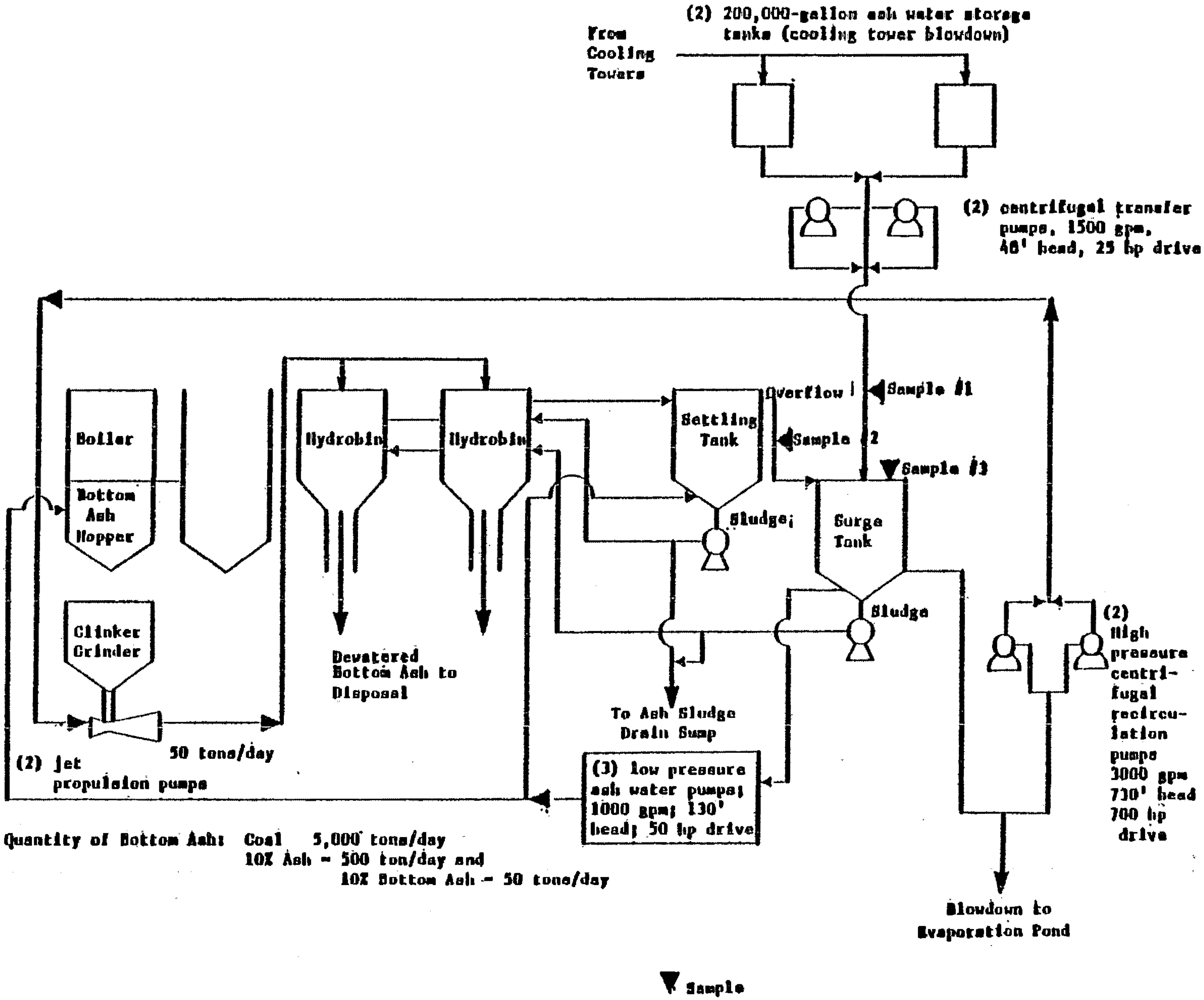
coal ash also increased the concentrations of calcium and sodium. The potential for precipitation of $CaCo_3$ exists in all three sampled streams based on the scaling tendency calculations. The greatest potential exists in the sluice water in the dewatering bin. This means that increased recycle or continuous operation of the current system can cause scale formation on pipes thereby reducing the flow rate in the pipes.

Plant 0822. This plant is a 447 MW coal-fired powerplant located in northwestern Colorado. The plant consists of two units: Unit 1 completed in 1965 and Unit 2 in 1976. The facility is a baseload plant using cooling towers for condenser heat dissipation, dry fly ash transport, and a zero discharge bottom ash sluicing system. The plant burns a bituminous coal from USBM Coal District 17. The plant is sufficiently close to the coal mine (nine miles) to be considered a mine-mouth operation. Plant water is drawn from a nearby river. The facility utilizes an RCC vapor compression distillation unit to recover recycleable water from cooling tower blowdown. All final wastewaters are ultimately handled by an evaporation pond. A general description along with a flow diagram (figure VII-23) of this plant has been provided in the fly ash subsection.

The flow scheme for the bottom ash sluice system is illustrated in figure .VII-44. Bottom ash from the boiler is jetted to one of two United Conveyor dewatering bins (one bin is in operation while the other is being drained). The overflow from the dewatering bin flows by gravity to a solids settling tank. Sludge from the settled ash material is pumped back to the hydrobin. The overflow from the settling tank flows to the surge tank and then to the two centrifugal pumps which supply water to the ash jet pumps. Makeup water, which consists of cooling tower blowdown and some plant raw water, is added to two ash water storage tanks. The makeup water is directed either to the surge tank or to the high- and low-pressure ash water pump suction headers. Under normal operation, the ash water makeup equals the water retained by the bottom ash after dewatering, the water used for wetting fly ash prior to unloading and small losses from evaporation in the bottom ash hopper. Any solids which settle to the bottom of the surge tank are pumped as sludge back to the dewatering bins.

Once the dewatering bin fills with bottom ash, the bottom ash sluice is switched to the other bin. The filled bin is then drained of the sluice water. When the bottom ash is sufficiently dewatered (after about 8 hours), it is dumped into an open truck and hauled to the mine for disposal. The sluice water makeup from the cooling tower blowdown is treated with a scale inhibitor (NALCO). The cooling towers operate between 8 and 10 cycles of concentration with a dissolved solids level of 1,200 mg/l.

The current bottom ash sluice system was designed as a part of Unit 2. Thus, for Unit 2, the system is an original design while for Unit 1, it is a retrofit. Prior to the construction of the current system in 1975, the plant used a once-through sluice operation in which both fly


(2) 200,000-gallon ash water storage tanks (cooling tower blowdown)
From Cooling Towers
(2) centrifugal transfer pumps, 1500 gpm, 48' head, 25 hp drive
Overflow
Sample #1
Sample #2
Sample #3
Boiler
Bottom Ash Hopper
Clinker Grinder
Hydrobin
Hydrobin
Settling Tank
Sludge
Surge Tank
Sludge
Dewatered Bottom Ash to Disposal
(2) jet propulsion pumps
50 tons/day
To Ash Sludge Drain Sump
(3) low pressure ash water pumps; 1000 gpm; 130' head; 50 hp drive
(2) High pressure centrifugal recirculation pumps 3000 gpm 730' head 700 hp drive
Blowdown to Evaporation Pond
Sample

Quantity of Bottom Ash: Coal 5,000 tons/day
10% Ash - 500 ton/day and
10% Bottom Ash - 50 tons/day

Figure VII-44
BOTTOM ASH HANDLING SYSTEM FOR PLANT 0822

ash and bottom ash were sluiced to a pond. The solids resulting from these operations have since been removed and disposed of at the mine. The pond now serves as a water storage pond to be used in the event of drought conditions.

The bottom ash handling system supplier for plant 0822 is United Conveyor Corporation. The following discussion provides specific information concerning the major equipment for the bottom ash handling system.

Two ash water storage tanks hold the makeup water to the ash handling system. These tanks have volumes of 200,000 gallons each. High and low water level switches are used to control the water level in these tanks.

Two Bingham horizontal end suction, back pullout, centrifugal pumps each rated at 150 gpm, 48 feet head are driven by 25 HP, 1,200 rpm Westinghouse motors. These pumps supply water to the surge tank from the ash water storage tanks and are automatically controlled by surge tank hi-low level switches.

Two high pressure pumps supply recirculation water to the jet pumps at the bottom ash hoppers from the surge tank. These pumps are Bingham horizontal, single stage, axially split, double suction centrifugal pumps each rated at 3,000 gpm, 730 feet head and are driven by 700 hp, 3,600 rpm Reliance motors. Start-stop control switches are located on the bottom ash panel.

Three low pressure ash water pumps supply ash water from the surge tank at a pressure of approximately 50 psig to the surge and settling tanks for sludge removal and flushing, and to the bottom ash hopper for fill, seals, flushing, and overflow supply. These pumps are Bingham horizontal end suction, back pullout, single stage centrifugal pumps each rated at 1,000 gpm, 130 feet head and are driven by 50 hp, 1,800 rpm Westinghouse motors. Automatic controls are located on the bottom ash panel and manual controls are locally placed.

The "jetpulsion" pumps are jet pumps located beneath the cylinder grinders. These pumps create the force necessary to convey the ash and water to the dewatering bins. Water for the "jetpulsion" pumps is supplied by the high pressure ash water pumps. These jet pumps are controlled on and off by associated two-way rotary sluice gates located in the discharge line of each pump. The sluice gates are solenoid operated from the bottom ash control panel by OPEN-CLOSE switches.

Each of the two dewatering bins is designed to provide a net storage volume of 12,700 cubic feet or approximately 48 hours bottom ash storage capacity with both 1 and 2 at full load. Also, each bin is fitted with a 12 kw chromolox electric heater and an ash level detector which activates an alarm and a light on the control room panel when maximum ash level is reached. At this point the conveyor is stopped, the diverting gates are switched, and the conveying operation is then restarted by an operator.

Separate settling and water surge tanks are provided to recover the ash water used in the handling of bottom ash and pyrites. The settling tank is sized to provide flow-through water velocities sufficiently low to precipitate most particulate matter larger than 100 microns. Sufficient volume is provided in the surge tank to absorb the severe imbalance between input and output flows that occur when the system progresses through the ash transport and dewatering cycle.

The manpower increase due to the retrofitted ash handling systems is 15. This number includes both fly ash and bottom ash systems for both maintenance and operation.

The maintenance problems with the bottom ash handling system are nominal. The most frequently recurring problem is the erosion of the impellers and casings of the high pressure recirculation pumps. There are no problems with fines in the operation of the dewatering bins, e.g., screen plugging or overflow into the settling tank causing plugging of the sludge pumps. Some problems arose in retrofitting the bottom ash system; the usual pipe rerouting, use of old pipe, and outage time were required for the system installation.

Samples were taken at three different locations in the bottom ash sluicing system. These locations were:

1. A sample was taken of the system makeup stream from the cooling tower blowdown water,

2. A sample was taken of the settling tank overflow to the surge tank, and

3. A sample was taken from the surge tank.

These samples provide an indication of the trace elements, major species, and carbon dioxide content of transport streams before and after the surge tank, and of makeup water to the system. The trace elements which were analysed include silver, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, and zinc. The major species analyzed were magnesium, calcium, sodium, phosphate, sulfate, chloride, silicate, and carbon dioxide. The results of these analyses are reported in tables VII-28 and VII-29.

The sampling results indicate that the contact of the sluice water with the bottom ash, as reflected in the settling tank overflow species values relative to the other two streams, raises the concentrations of some species. The trace elements, which increased due to ash contact are silver, cadmium, chromium, selenium, and zinc. For the major species, an increase in carbonate concentration is reflected in the carbon dioxide values. Decreases in concentration

Table VII-28

TRACE ELEMENTS PRIORITY POLLUTANTS CONCENTRATIONS[1,2] AT PLANT 0822

(ug/l)

	Cooling Tower Blowdown	Settling Tank Overflow	Surge Tank
pH	8.0	6.3	6.7
Temp. (°F)	89.0	130.0	126.0
Silver	<0.1	0.4	<0.1
Arsenic	49.0	3.0	3.0
Beryllium	<0.5[3]	<0.5	<0.5
Cadmium	<0.5	2.0	<0.5
Chromium	<2.0	10.0	<2.0
Copper	47.0	8.0	15.0
Mercury	<0.2	<0.2	<0.2
Nickel	<0.5	<0.5	<0.5
Lead	<3.0	<3.0	<3.0
Antimony	<1.0	<1.0	5.0
Selenium	<2.0	5.0	6.0
Thallium	<1.0	<1.0	<1.0
Zinc	95	145	410

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[1] All trace element analyses were done in duplicate; the two values were averaged.

[2] All concentrations are for the dissolved, not total, concentration.

[3] The value <0.5 indicates that the concentration was below the detection limit which in this case is 0.5 ppb for beryllium.

Table VII-29

MAJOR SPECIES CONCENTRATIONS[1,2] AT PLANT 0822

(mg/1)

	Cooling Tower Blowdown	Settling Tank Overflow	Surge Tank
Calcium	365	365	370
Magnesium	120	92	90
Sodium	210	145	150
Phosphate (PO_4)	3.3	0.17	0.09
Sulfate (SO_4)	1215	1203	1165
Chloride ($Cl-$)	211	112	125
Silicate (SiO_2)	57	36	35
Carbonate ($CO_3=$)	60	120	360

---

[1] Ca, Mg, Na were analyzed in duplicate; values are averages.

[2] All values reflect dissolved, not total, concentrations.

from the makeup source to the recycle loop are observed for *arsenic* and copper and for magnesium, sodium, chloride, and silicate, which indicates that a cycling effect does not exist in this system for these species.

On the basis of the sampling analyses, the Agency determined the tendencies for scaling for various species in the makeup and recycle streams by using an aqueous equilibrium program. The amount of scaling which may actually exist is contingent upon the amount of the species present and any other inhibitor additives which may be present. Only one sample species represented any driving force for precipitation. This species was $CaCO_3$ for the cooling tower blowdown makeup water stream.

In summary, this plant has achieved zero discharge by using evaporation ponds. No significant mechanical problems have occurred since the installation of this bottom ash system in 1974, and no significant problems arose during the retrofitting procedure. Chemically, some increase in trace element priority pollutants and major species concentrations has been observed due to contact with the ash. The potential exists for scaling $CuCo_3$ in the makup water stream. However, neither scaling nor corrosion has been a problem in the operation of this system.

Plant 1811. This plant is a 615-MW electric power generating station located in Northern Indiana. The plant uses a wet recirculating ponding system to handle bottom ash. This ash is generated by two cyclone-type boilers of 194 and 422 MW each. The coal ash content is 10 to 12 percent with 11 percent as the average. This bituminous coal is obtained from Bureau of Mines Coal Districts 10 and 11. The bottom ash sluicing recycle system was retrofitted in the early 1970's. The dry fly ash handling system was retrofitted early in 1979. Both of these systems were designed and installed by United Conveyor Corporation.

The bottom ash sluicing system is characterized by a bottom ash storage area, a series of settling ponds, and a recirculation or final pond. Figure VII-45 presents the sluice system flow diagram for the plant. Only one primary and one secondary pond is used during operation of the sluicing system. The sluice lines shown, other than the bottom ash sluice, are used to transport sump water to the ponds. Also, the discharge from a package sewage treatment facility is sent to the primary settling pond.

The hydroveyor line, which was used to sluice fly ash to the ponds, is used as a backup to the normal ash sluice pipes. The main sluice pumps for the bottom ash are jet pumps which discharge at a pressure of 230 psig at the runoff area. The larger unit 8 has two 10 inch sluice lines (including one spare) which transport the ash one-quarter of a mile to the slag runoff area. The smaller unit 7 has one 10 inch sluice line. The flow rate used to transport the bottom ash to the runoff area is approximately 2 MGD. The ash is sluiced for 1 to 2 hours each shift (depending on the load) with 10 minutes of flushing

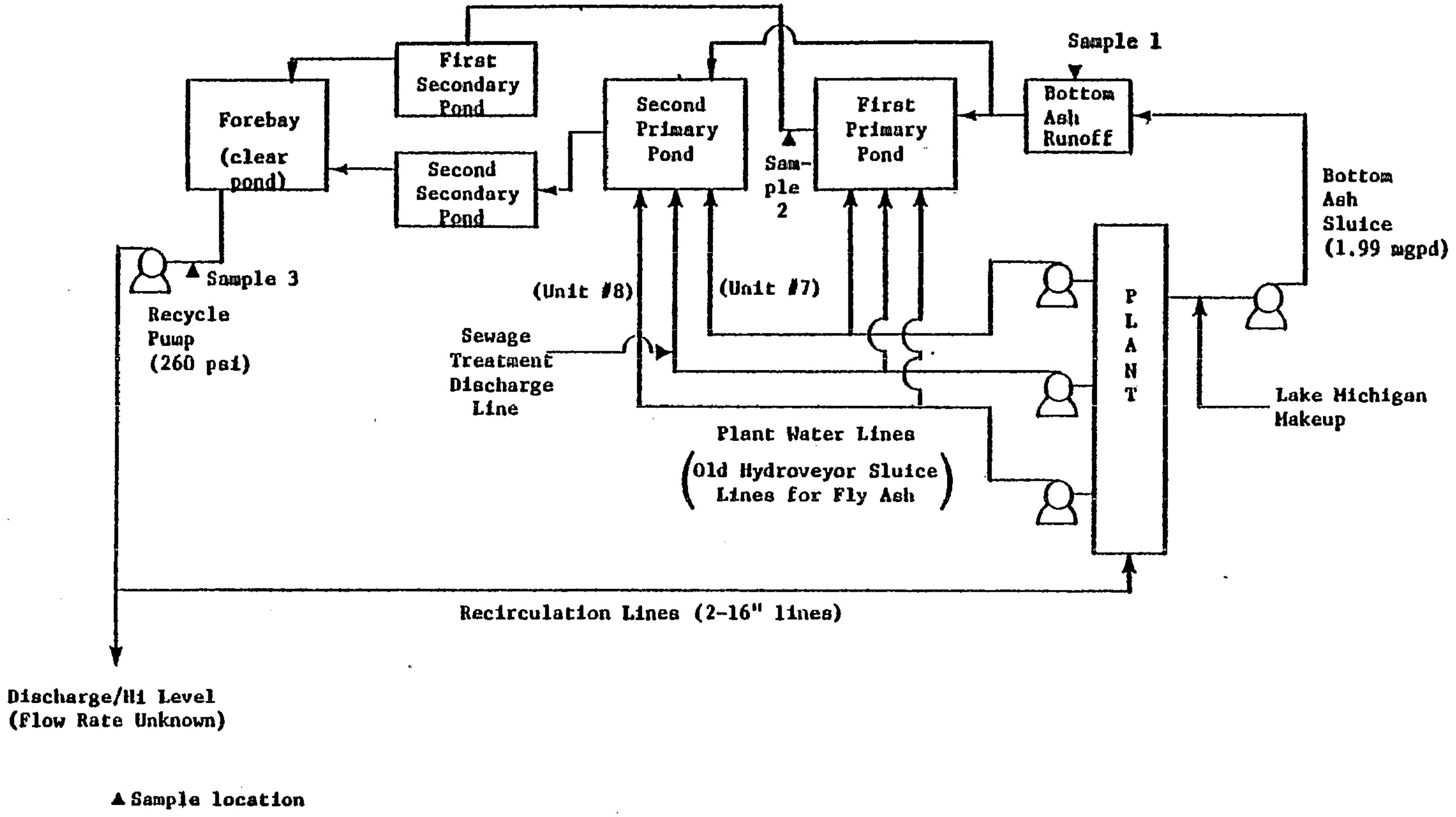
First Secondary Pond
Forebay (clear pond)
Second Secondary Pond
Second Primary Pond
First Primary Pond
Sample 1
Bottom Ash Runoff
Sam-ple 2
Bottom Ash Sluice (1.99 mgpd)
Sample 3
Recycle Pump (260 psi)
(Unit #8)
(Unit #7)
P L A N T
Sewage Treatment Discharge Line
Plant Water Lines (Old Hydroveyor Sluice Lines for Fly Ash)
Lake Michigan Makeup
Recirculation Lines (2-16" lines)
Discharge/Hi Level (Flow Rate Unknown)
▲ Sample location

Figure VII-45

PLANT 1811 FLOW DIAGRAM FOR BOTTOM ASH HANDLING before and 15 to 20 minutes afterwards. The surface areas of the two, primary settling ponds are 4.2 acres (182,900 feet^2) and 4.4 acres (192,200 feet^2). The areas of the two secondary ponds are 2.09 acres and 3.66 acres. The forebay or final pond has an area of 0.1 acres (5,188 feet^2). Three centrifugal pumps are located at the forebay which are used to recirculate the sluice water back to the bottom ash pump (a distance of 1/2 mile) as well as the general plant water system through one of two existing lines (16 inches diameter). These recirculation pumps supply sluice water to the bottom ash pump at a discharge pressure of 260 psig. A single pipe exists downstream of the forebay recirculation pumps which allows for the discharge of sluice water from the recirculating system. This discharge is initiated during upset conditions but is under complete control of the plant operators. This discharge is estimated to occur 2 days out of 7. The water is transported to Lake Michigan. Since this occurs intermittently, the flow rate was difficult to quantify. Makeup water to the bottom ash sluicing system enters the system at the sluice pumps from Lake Michigan. Makeup water is required because of pond evaporation, pond percolation, and water losses by removal of wet bottom ash. The amount of ash handled by the bottom ash sluicing system was estimated by 1978 FPC figures given by Plant 1811 personnel.

In 1978, the amount of bottom ash collected was 72,200 tons. The operating and maintenance cost associated with the sluicing operation was $67,300 for 1978. The hauling and disposal of the bottom ash at the landfill site was contracted out and cost $86,900 in 1978. Some of the bottom ash was sold which yielded $11,400.

Operating problems associated with the sluice system are nominal. Occasional broken lines and ruptured slag pumps require periodic maintenance, but this is considered normal. One major operating problem is pond sluice water percolation. The ponds are located at a higher elevation than a nearby plant and national park. These ponds are not sealed and the sluice water seeps into offsite water systems. The amount of percolation increases during periods of high water levels in the pond. Future plants are expecting to build a lined pond to prevent this percolation.

The operating manpower required to run the sluicing system is one man part-time in the control room each shift and one man part- time monitoring the slag sluicing operation. This requirement totals to one man full-time for equipment maintenance. Most heavy maintenance work is done during planned outages.

The recycle portion of the sluice system, i.e., the forebay and recycle line, was retrofitted in the early 1970's as a result of a decision to collect all process waters at one location. No problems were incurred due to the retrofit of the system.

Samples were taken at three different locations in the bottom ash sluicing system. These locations, which are designated in figure VII-45, are:

1. the bottom ash discharge point,
2. the primary pond overflow, and
3. the forebay outfall.

These samples were taken to provide an indication of the levels of trace elements and major species in the recirculating/sluicing system. The trace elements assayed were silver, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, and zinc. The major species assayed were magnesium, calcium, sodium, phosphate, sulfate, chloride, silicate, and carbon dioxide. The results of these analyses are reported in tables VII-30 and VII-31.

The sampling results are inconclusive. Most of the concentrations are low, except for the sulfate and zinc. There is essentially no indication of an effect on trace metal concentrations due to contact of the sluice water with the ash.

On the basis of sampling results, EPA determined the tendencies for scaling for various species in the recycle streams by using an aqueous equilibrium program. The results of this analysis indicated that the potential for scaling of four major species was very low in all three sample streams.

The feasibility of zero discharge using complete recycle with ponding for bottom ash cannot be confirmed by the system used at this plant because it requires intermittent discharge to maintain a steady-state water balance in the system; however there were no mechanical or chemical problems related to the recycle operation. The problem with percolation could be alleviated by lining the existing ponds.

Plant 1809. This plant is a 736 MW electric power generating station. Four boilers currently in operation burn bituminous coal which has an ash content of 10 to 12 percent. The boilers are of the wet bottom cyclone type and produce a relatively large amount of bottom ash slag. The plant utilizes a wet recirculating ponding system to handle both fly ash and bottom ash. Water is obtained from a nearby creek for use in the sluicing operation. A flow diagram of the ash handling system appears in figure VII-35.

The bottom ash sluicing system was retrofitted in 1974 along with the fly ash sluicing system and Unit 12, the largest of the steam generators (520 MW). All systems were designed and installed by Allen-Sherman-Hoff, retrofitted for Units 4, 5, and 6, and new for Unit 12. The principal reasons for installing the ash sluicing recycle system were the requirements of discharge regulations and the decision to collect and handle all process waters at one location. The fly ash and bottom ash is produced at a ratio of 26 percent fly ash to 74 percent bottom ash. In 1978, approximately 48,600 tons of fly ash were collected and 136,000 tons of bottom ash were collected.

Table VII-30

TRACE ELEMENTS PRIORITY POLLUTANTS CONCENTRATIONS[1,2] AT PLANT 1811

(ug/l)

	Forebay Outfall	Primary Pond Overflow	Bottom Ash Discharge
pH	6.5	6.7	6.3
Temp. (°F)	77	79	85
Silver	<0.1[3]	<0.1	<0.1
Arsenic	<1.0	2	6
Beryllium	<0.5	<0.5	<0.5
Cadmium	6.0	5.0	8.0
Chromium	<2	<2	<2
Copper	14	3	10
Mercury	<1	<1	<1
Nickel	27	16	17
Lead	<2	<2	<2
Antimony	<3	<3	<3
Selenium	<2	<2	<2
Thallium	10	10	25
Zinc	270	180	90

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[1] All trace elements analyses were done in duplicate, and the two values were averaged.

[2] All concentrations are for the dissolved, not total, concentration.

[3] The value <.1 indicates that the concentration was below the detection limit which in this case is .1 ppb for silver.

Table VII-31

MAJOR SPECIES POLLUTANTS CONCENTRATIONS[1,2] AT PLANT 1811

(mg/l)

	Forebay Outfall	Primary Pond Overflow	Bottom Ash Discharge
Calcium	69	54	74
Magnesium	14	11	19
Sodium	40	43	36
Phosphate (PO_4)	<0.06	<0.06	<0.06
Sulfate (SO_4)	273	241	250
Chloride (Cl)	8	8	8
Silicate (SiO_2)	5	<3	4
Carbonate (CO_3)	60	300	600

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[1] Ca, Mg, Na were analyzed in duplicate; the values are averaged.

[2] All values reflect dissolved, not total, concentrations.

A jet pump sluices the bottom ash from the slag tanks to the bottom ash runoff area. Two 12-inch diameter pipes are used to sluice the bottom ash; one from the Boiler 12 slag tank and one from Boilers 4, 5, and 6 slag tanks. The bottom ash sluice water flow rate is approximately 3 MGD. At the bottom ash runoff area, the bottom ash slag is bulldozed into piles and is sold for use as a road bed aggregate. The runoff area is composed of two primary ponds, 11,536,000 and 14,198,000 gallons capacity, and one small secondary pond. Only one primary pond operates at a time. The bottom ash is sluiced every 4 hours for 30 to 45 minutes. The piping used for conveying the bottom ash is cast iron in the plant area and cast basalt (Sch. 80) outside the plant area. From the secondary pond, the sluice water overflows into the final pond for recirculation back to the jet pumps.

At the final pond, facilities are available for a discharge to Lake Michigan. These facilities consist of two pipes from the main conveying lines to Lake Michigan for intermittent and upset conditions. The discharge is actuated by gravity overflow. A discharge condition prevails when Unit 12 is operating. Usually when Units 4, 5, and 6 are operating and Unit 12 is down, the discharge condition does not exist. The final pond also receives a large amount of water from the miscellaneous sump system; thus, during heavy rainfall periods, a discharge condition often exists. Thus, Plant 1809 is not strictly a zero discharge plant. It does provide for a discharge under fairly consistent conditions when Unit 12 is operating. This discharge stream was not quantified by plant personnel. The discharge is not used to prevent scaling of the ash handling components, but is used solely to remove the surplus water which accumulates. This surplus water is being considered for use as makeup to the cooling tower.

Operating problems associated with the sluice system are nominal. Occasional instances of low pH have caused some pipe corrosion; however, lime addition for pH adjustment has alleviated much of this problem. Scaling has historically not been a maintenance problem. Suspended solids have caused pump erosion problems on an intermittent basis. Currently, the creek is used as the makeup water source. High flow situations, e.g., after heavy rainfall, result in a poor quality makeup water; also, incomplete bottom ash settling caused some wear on pumps. Control of final pond water flow and installation of surface booms for floating material collection has mitigated much of the solids problem. The piping is rolled to maintain even wear on all inside sluicing surfaces. This procedure is not unusual. One area which requires significant maintenance is the sluicing jets and recirculation pumps. These pumps do not have spares and therefore must be frequently checked and maintained so as not to cause a shutdown of the sluicing operation.

The primary ponds are cleaned annually and only one primary pond is cleaned per year. Ash hauling is contracted to an outside trucking firm.

The bottom ash is sold for commercial use, which provides a credit for the ash. According to the 1978 FPC data provided by the plant personnel, the cost for collection and disposal of the bottom ash was $79,200 and the sale of the bottom ash provided a $29,900 credit.

The bottom ash ponding recycle sluicing system for plant 1505 was installed in 1974. At the same time the fly ash sluice water recycle system and Unit 12 was installed. Thus, the recycle portion of the pond system is a retrofit system for units 4, 5, and 6. The reason for retrofitting a recycle system, i.e., a final pond and return line, was in part due to discharge regulations since the plant is bounded by a National Park, a town, and Lake Michigan. An additional motive was to collect all discharge streams in the final pond for common treatment, if needed.

The retrofit of the recycle line did not enable the plant to achieve zero discharge because of water balance problems. Water is accumulated especially when Unit 12 is operating. The plant is in a low net evaporation climate. When the plant installed the recirculation system, the already-existing main sluicing jet pumps and the new recirculating pumps were not spared. This has presented a maintenance problem and a need for redundancy by the plant is recognized.

The plant claims that it is difficult to achieve zero discharge by retrofitting a recycle loop on a ponding system for two reasons: it is difficult to tie up all the streams into one collection point, and it can be done only if the already-existing systems can be totally segregated. There is also the effect on electricity generation to be considered; higher auxiliary power requirements reflect lower net power generation. Plant 1809 personnel indicate that the technology to retrofit bottom ash systems is more available than that for retrofitting fly ash recycle systems. Cyclone boilers produce mostly bottom ash; however, cyclones are no longer available as a technology, primarily only way for plant 1809 to meet a zero discharge requirement is to install evaporators which would increase the auxiliary power requirements.

Any new expansion of generating capabilities would have to be met with pulverized coal boilers. No market for bottom ash from these boilers has been found by plant 1809 personnel, so the bottom ash handling systems would have to be segregated. Also, facilities to handle a larger percentage of fly ash would be installed with a pulverized unit.

Samples were taken at three different locations in the bottom ash sluicing system. These locations are shown in the bottom ash sluicing system diagram in figure VII-35 and are described as follows:

1. A sample was taken of the miscellaneous sump water,

2. A sample was taken of the bottom ash pond overflow, and

3. A sample was taken of the recirculating water from the final pond.

These samples provide data on the trace element, major species, and carbon dioxide content of transport streams at the settling ponds and of the sump water before the ponds. The trace elements analyzed for were silver, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, lead, antimony, selenium, thallium, and zinc. The major species assayed were calcium, magnesium, sodium, phosphate, sulfate, chloride, silicate, and carbon dioxide. The results of these analyses are presented in tables VII-32 and VII-33.

Results from the sampling of trace elements indicate that only one concentration increased due to exposure to the bottom ash. The concentration of nickel in the bottom ash pond overflow is higher than in the final pond effluent which serves as the makeup water to the bottom ash sluicing system.

On the basis of this sampling and analysis, the tendencies for scaling in the sluice streams were determined through an aqueous equilibrium program. Based on the aqueous equilibrium results, calcium carbonate theoretically has the greatest potential for precipitation in the sluice water from the final pond; next greatest in the bottom ash pond overflow, and the least potential in the miscellaneous sump stream. None of the streams indicated a high scaling potential.

The feasibility of a closed-loop zero discharge operation cannot be established based on the information available from this plant since there is fairly continous discharge. This discharge is due to an inherent accumulation of water in the recyle loop under certain operating conditions.

LOW-VOLUME WASTES

One treatment technology applicable for the treatment of low- volume waste streams is vapor-compression evaporation (VCE). Although this method of waste treatment is energy intensive, it yields a high-purity treated water stream and significantly reduces the wastewater effluent flow. A number of the low-volume waste streams described in Section V are suitable for VCE treatment. These streams are:

1. Water Treatment

    - Clarifier blowdown (underflow)
    - Make-up filter backwash
    - Lime softener blowdown
    - Ion exchange softener regenerant
    - Demineralizer regenerant
    - Reverse osmosis brine
    - Evaporator bottoms

2. Boiler blowdown

3. Floor and laboratory drains.

Table VII-32

TRACE ELEMENTS/PRIORITY POLLUTANTS CONCENTRATIONS[1,2] AT PLANT 1809

(ug/l)[1]

	Sluice Water from Recirculation Pond	Bottom Ash Pond Overflow	Miscellaneous Sump
pH	7.9	7.9	7.7
Temp (°F)	80	85	80
Silver	<0.1[3]	<0.1	<0.1
Arsenic	66	12	12
Beryllium	<0.5	<0.5	<0.5
Cadmium	0.7	1.0	1.0
Chromium	3	<2	3
Copper	5	3	16
Mercury	<1.0	<1.0	4.0
Nickel	17	29	<3
Lead	<2	<2	3
Antimony	9	8	<3
Selenium	4	<2	<2
Thallium	62	56	6
Zinc	70	50	100

---

[1] All samples were analyzed in duplicate, the values were averaged.

[2] All analytical values are for dissolved concentrations, the samples were filtered initially.

[3] The value <.1 indicates that the concentration was below the detection limit which is 0.1 g/l.

Table VII-33

MAJOR SPECIES CONCENTRATIONS[1,2] AT PLANT 1809

(mg/l)

	Sluice Water from Recirculation Pond	Bottom Ash Pond Overflow	Miscellaneous Sump
Calcium	125	115	63
Magnesium	60	58	24
Sodium	50	48	19
Phosphate (PO_4)	0.06	<0.06[3]	0.11
Sulfate (SO_4)	633	650	149
Chloride (Cl)	16	18	14
Silicate (SiO_2)	6	5	5
Carbonate (CO_3)	1080	1020	1800

---

[1] Ca, Mg, Na samples were analyzed in duplicate; the results were averaged.

[2] These concentrations reflect dissolved, not total, concentration.

[3] The value <.06 reflects a concentration below the detection limit which in this case is 0.06 mg/l.

The VCE process concentrates non-volatile effluents from these sources. This produces a concentrated brine which is usually ponded in arid regions or sent to a pond or treated in a spray dryer in non-arid regions (49).

Process Description

A schematic flow diagram of a VCE system is shown in figure VII-46. The wastewater is first treated in a feed tank to adjust the pH to between 5.5 and 6.5 for decarbonation. The stream is then pumped through a heat exchanger to raise its temperature to the boiling point. In some instances, softening may be required to prevent scaling in the heat exchanger. After passing through a deaerator which removes dissolved gases, the hot waste stream is combined with the slurry concentrate in the evaporator sump. This slurry is constantly recirculated from the sump to the top of the evaporator tubes. The slurry flows as a thin film down through the tubes and vaporizers. The vapor is compressed and introduced to the shell side of the tube bundle. As this stream condenses, it transfers its heat of vaporization to the brine slurry. The condensate that results on the shell side is pumped through the feed preheater to transfer as much heat as possible to the process before it is discharged from the unit. A portion of the brine slurry is continuously drawn off from the sump to maintain a constant slurry concentration (200,000 to 400,00 mg/l solids) (51, 52).

The formation of scale is avoided on heat transfer surfaces by preferential precipitation of calcium sulfate silica on seed crystals in the slurry. In addition, a small temperature difference across the heat exchanger tubing minimizes scale formation on the evaporating surfaces (39).

Effectiveness

VCE systems have taken streams containing between 3,000 and 50,000 mg/l of total dissolved solids (TDS) and have yielded a brine stream containing 200,000 to 400,000 mg/l TDS and a stream of water containing less than 10 mg/l TDS. In the event that there are significant amounts of priority pollutants present in the feed stream, it may be necessary to attach additional treatment equipment to the deaerator vent, e.g., carbon adsorption or incineration.

Brine Slurry Concentration and Disposal

Evaporation Ponds

For areas of the country where the net annual evaporation rate (gross evaporation minus rainfall) exceeds 20 inches a year, use of evaporation ponds for disposal of VCE waste brines may be a viable disposal method. Evaporation ponds are used as a final wastewater disposal method throughout the electric utility industry, primarily in

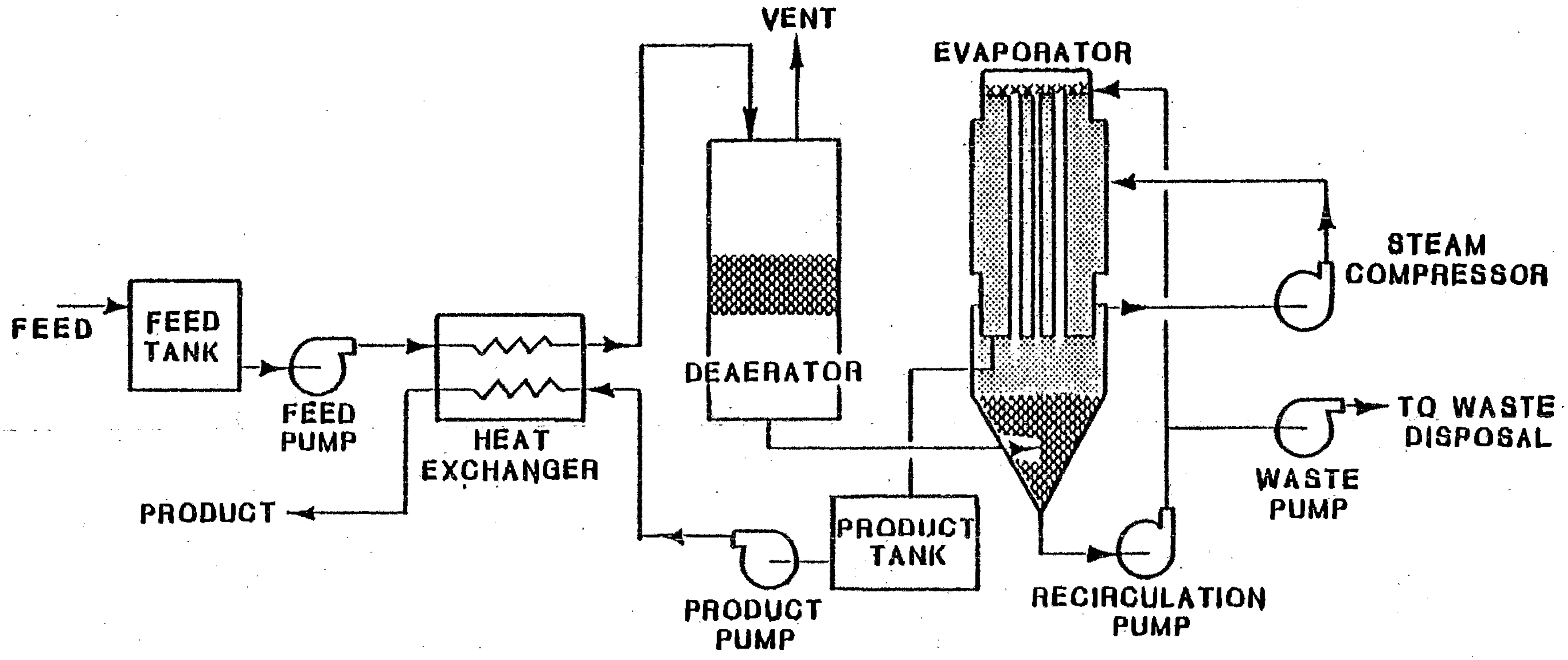
VENT
EVAPORATOR
STEAM COMPRESSOR
FEED
FEED TANK
FEED PUMP
HEAT EXCHANGER
DEAERATOR
TO WASTE DISPOSAL
WASTE PUMP
PRODUCT
PRODUCT TANK
RECIRCULATION PUMP
PRODUCT PUMP

Figure VII-46

SIMPLIFIED, SCHEMATIC DIAGRAM OF A VAPOR COMPRESSION EVAPORATION UNIT (50) the southwestern states; however, land cost and governmental regulations restrict the use of evaporation ponds at many plant sites.

Evaporation ponds use solar energy to evaporate wastewater and thereby concentrate dissolved solids in the wastewater. The ponds are constructed by excavation, by enclosing an area with dikes, by building dams, or by a combination of these methods. Ponds may require a liner to prevent seepage of wastewater into the natural pond water supplies. Typical liners are clay, asphalt, and PVC sheets. The area required for a single evaporation pond can be estimated by equation 24:

$$\text{Area (acres)} = \frac{19.5G}{V} \qquad (24)$$

where G is the wastewater flow rate in gallons per minute and V is the effective net evaporation rate in inches per year.

The effective net evaporation rate of pond water is less than the area net evaporation rate. This occurs because of the decreasing pond water vapor pressure with increased dissolved solids content of the pond water. Consequently, some systems use ponds in series where the effective evaporation rate of the first ponds is greater than the evaporation rate of the latter ponds. The pond depth required is equal to the wastewater flow rate in acre-feet per year divided by the pond area in acres required for evaporation. Additional depth is required for solids build-up in the pond.

Spray Drying

For areas of the country where evaporation by ponding is not feasible, thermal drying of the waste brine to produce a solid for disposal by land fill is an option. Spray dryers have been proposed as a suitable method for thermal drying of VCE waste brines.

In a spray dryer, the VCE waste brine is atomized either by a spray nozzle or a high-speed rotating disk. Hot combustion gases contact the atomized brine in the drying chamber and vaporize the water. The hot flue gases and dryed brine crystals pass through a baghouse for brine crystal removal before being vented to the atmosphere. Moisture content of the dried brine crystals is less than 5 percent (51).

METAL CLEANING WASTES

As explained in Section V, metal cleaning wastes are, periodic discharges that may occur only infrequently at many power stations. Since they are infrequent, many plants prefer to have them hauled off and treated by private contractors. Most of the expertise for treating cleaning wastes has been developed by the cleaning contractors. Current treatment methods include incineration, ash basin treatment, and physical-chemical treatment. In addition, treatment by vapor compression evaporation also has been considered.

Treatment Methodologies

Disposal by Incineration (Evaporation). Incineration (evaporation) of boiler chemical cleaning solutions has gained increasing popularity since its first commercial application in 1971 (53). A number of utilities have used such a process for disposal of waste boiler cleaning solutions of various types, including ammoniated EDTA, ammoniacal bromate, citric acid, and hydroxyacetic/formic acid containing ammonium bifluoride (54, 55, 56). To date, well over 125 such incinerations of ammoniated EDTA waste solutions alone have occurred.

The incineration procedure involves the controlled injection of spent boiler cleaning chemicals into the firebox of an operational boiler (see figure VII-47). As the solution is injected, water is vaporized and the organics are combusted. The organic materials are reduced to such compounds as N_2, CO_2, and H_2O while iron and copper deposits from the cleaning are transformed to oxides (57). These boiler chemical cleaning wastes are combustible to some extent due to these organic molecules and metal compounds. Ammoniated EDTA has been estimated to have a heat value of 2,000 Btu/pound.

Injection rates are dependent on the fan and fuel capacity of the boiler and must be determined on an individual basis. However, the gallon per minute incineration rate has been equivalent to approximately 2 to 5 percent of the steam flow of the boiler in a number of cases (58). Injection rates range from 20 to 180 gallons per minute.

Solvent injection has been tested in coal, oil, and gas fired boilers, both above and below the burners, and at various spray angles. Tests have shown that disposal through incineration has successfully captured metals. At times, as high as 98 percent iron and 95 percent copper from the injected waste solutions have been retained in the furnace.

The transition of metal ions to oxides is chemical in nature. These oxides are then physically transformed to small particles and either leave the stack or are trapped as deposits between the point of combustion and the stack outlet. Since ash is primarily composed of metallic oxides in various proportions, it would be expected that deposition would occur along with bottom or fly ash, in pollution control equipment or on walls of the furnace or stack.

Other substances which are of concern were also evaluated in incineration studies. Such cases concerned the disposal of ammoniacal bromate, and hydroxyacetic/formic acid containing ammonium bifluoride. Thermogravimetric analysis revealed that sodium bromate was converted to sodium bromide and oxygen at 752 F and that no obnoxious products were formed at temperatures up to 1,850 F (54). Actual incineration tests on these solutions in a 860 F boiler revealed no liberation of halogen gas or other obnoxious gases.

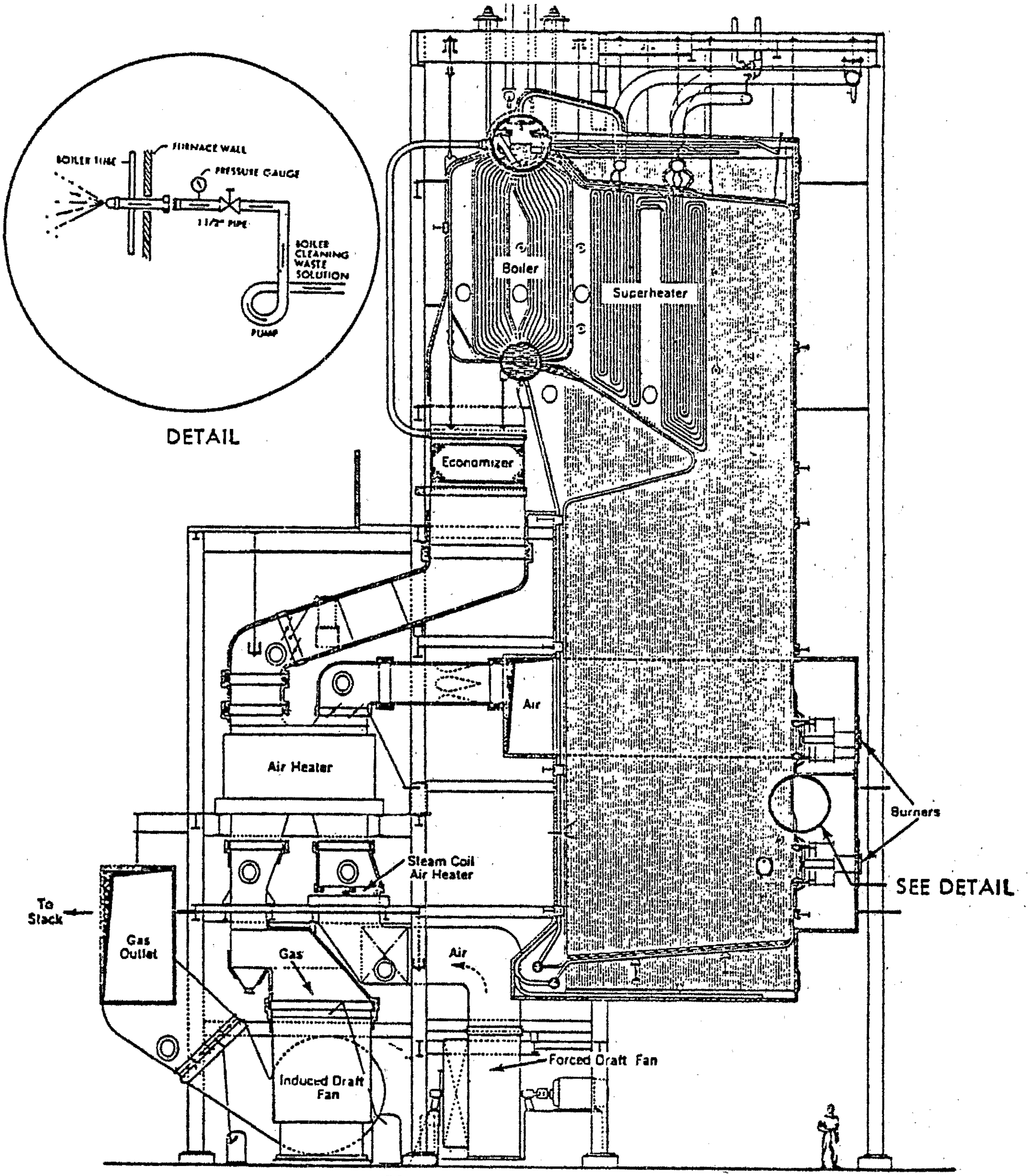
BOILER TUBE
FURNACE WALL
PRESSURE GAUGE
1 1/2" PIPE
BOILER CLEANING WASTE SOLUTION
PUMP
DETAIL
Boiler
Superheater
Economizer
Air
Air Heater
Burners
SEE DETAIL
Steam Coil Air Heater
To Stack
Gas Outlet
Gas
Air
Induced Draft Fan
Forced Draft Fan

Figure VII-47

TYPICAL PIPING DIAGRAM AND LOCATION FOR INCINERATION OF BOILER CHEMICAL CLEANING WASTES (68)

Some tests conducted during incineration of boiler cleaning wastes have shown that sulfur dioxide (SO_2) and the oxides of nitrogen (NO_x) have been reduced in stack emissions. Explanation of the lower NO levels may stem from the dissociation of water, which replaces oxygen supplied by air thereby lowering the air and nitrogen supply to the furnace (58).

Ash Basin Treatment. A number of utilities employ ash ponds for the treatment of boiler chemical cleaning wastes (57, 59). The theory behind such a treatment scheme is that the chemical/physical nature of the ash pond environment will treat those wastes as well as conventional lime treatment.

A number of basic characteristics of the ash pond are utilized to treat these wastes. The most important characteristic is pH, since metals are removed as precipitated hydroxides above a certain pH. Many ash ponds are naturally alkaline and thus have a good potential for metal-hydroxide formation.

The presence of fly ash in ash ponds also appears to be an aid in the treatment scheme (60). Fly ash has been used in water treatment to increase the rate of floc growth and to enhance floc settling properties. Some studies have shown that ashes which raise the pH of ash sluice water can be expected to precipitate heavy metals (60).

In one of the demonstration projects on ash basin treatment, dissolved oxygen content of the ash pond was felt to be an important factor (60). In theory, its presence provided the oxidizing potential to convert iron ions from the ferrous to the ferric state, the latter which could be precipitated at a lower pH than the former.

The dilution factor of the ash pond is also felt to be important in breaking the ammonia complex bond in the ammoniacal bromate solution, thus allowing the precipitation of copper. In order to achieve equivalent metal removal, the increase in the concentration of the metal in the ash pond effluent must be equal to or less than the concentration achievable by lime precipitation divided by the dilution factor.

Physical/Chemical Treatment. A number of treatment schemes employing physical/chemical processes have been tested, designed, and implemented for the treatment of boiler chemical cleaning wastes. The basic mechanism behind these treatment schemes involves neutralization with caustic or lime followed by precipitation of the metal hydroxide compounds (57, 61, 62, 63, 64, 65). However, there are a number of additional unit processes which have been employed on certain waste chemical solutions in order to increase the degree of attainable reduction of certain constituents. These additional unit processes include: mixing with other metal cleaning waste sources, oxidation, sulfide addition, filtration, and carbon adsorption.

In the treatment of waste boiler chemical cleaning solutions the use of these unit processes, either alone or in combination with others, is dependent upon which waste solution is being treated. Various characteristics of individual waste streams make the use of certain unit processes feasible. A description of the use of these processes as they apply to boiler chemical cleaning wastes follows.

Ammoniated Citric Acid. Ammoniated citric acid boiler cleaning wastes contain amounts of complexed iron and copper. Chelation of iron by citrate is the first step of the two step process which is followed by ammonia addition to complex copper. Dilution is necessary to dissociate the ammonia-copper complex and will aid in breaking the iron-citrate chelate. Adjustment of pH upwards will further lower the degree of complexation as figure VII-48 illustrates.

Aeration of this waste has been recommended in order to oxidize cuprous and ferrous ions to the cupric and ferric state, thus lowering the pH needed to precipitate the copper and iron (57).

Addition of sodium sulfide after aeration under acidic conditions in one treatment scheme reduced metal concentrations due to the precipitation of metal sulfides. In this treatment scheme, clarifier overflow was filtered through a dual media gravity filter to produce final effluent with iron and copper concentration below one (1) mg/l (57).

Ammoniated EDTA. Waste ammoniated EDTA boiler and chemical cleaning solutions are difficult to treat due to the metal complexes which are present. EDTA is a hexadentate ligand which chelates iron, while the ammonia forms complexes with copper. However, these wastes are effectively treated to below the one (1) mg/l level for iron and copper using a combination of unit processes.

Dilution in plant wastes such as air preheater wastes and boiler fireside wastes have effectively achieved the dissociation of these complexes and subsequent removal of the copper (57, 66). The presence of sulfides in these wastes, resulting from burning sulfur-containing fuels, helps remove copper by the formation of insoluble copper sulfide (57, 67). When dilution is followed by lime addition to pH levels of approximately 13, reduction of iron and copper levels below 1 mg/l may be achieved (57). Addition of a polymer to aid in flocculation has been used in order to achieve maximum removal of metals (57).

Ammonical Sodium Bromate. Reduction of total copper in waste ammoniated sodium bromate solutions first requires the dissociation of the ammonia-copper complexes. This step is required in order to free the copper, thus allowing it to form insoluble hydroxide precipitates.

Figure VII-49 illustrates the degree of complexation of NH_3 on Cu^{2+} to be a function of dilution. In the left hand graph, pCu^{2+} first increases as ammonia equilibrium forces it to enter into solution (thereby shifting the copper species to the lower ammoniated form) then decreases as dilution effects predominate. The second graph shows the degree of complexation decreasing with dilution due to the

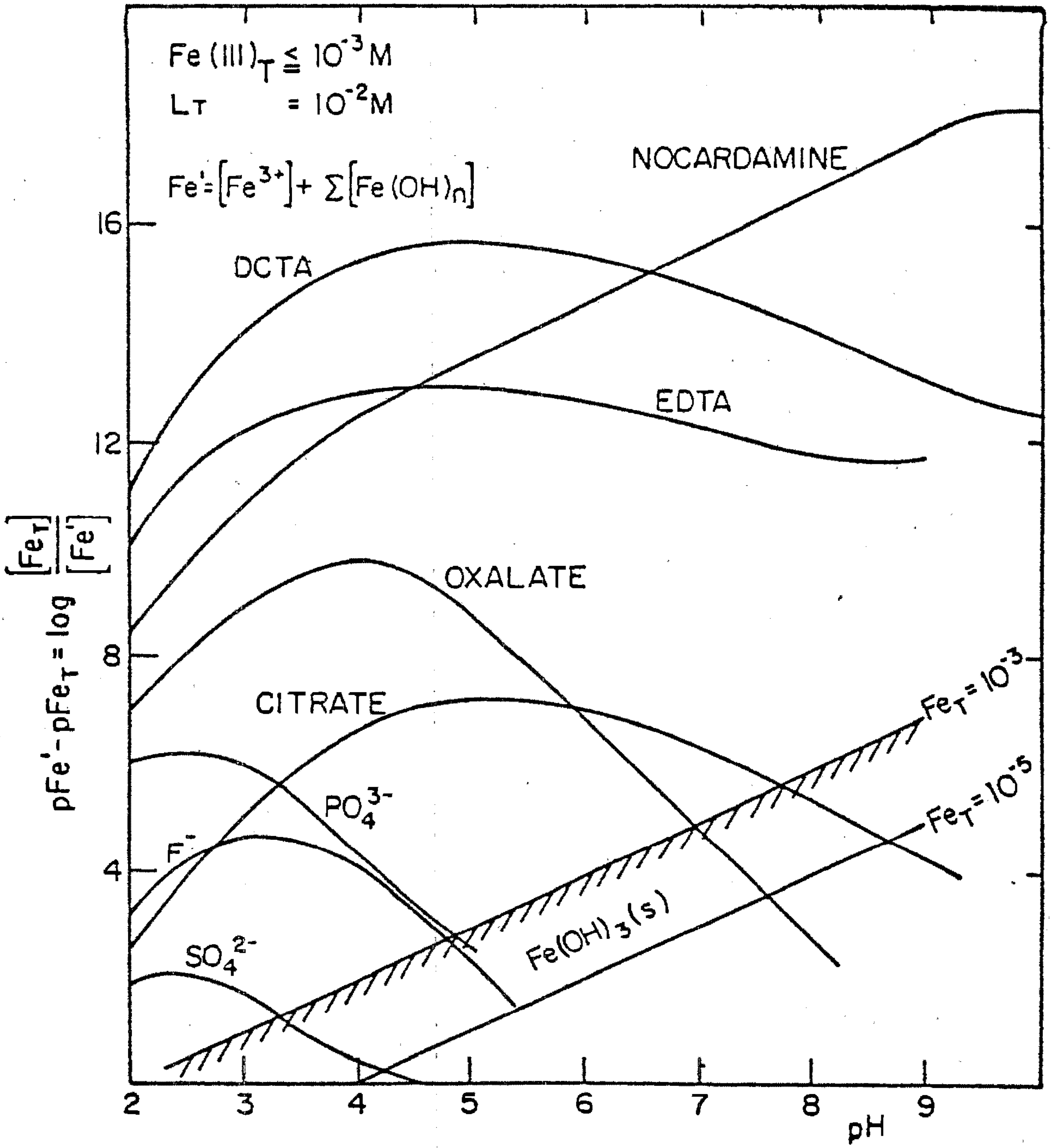

Figure VII-48

COMPLEXING OF Fe(III) (69)

The degree of complexation is expressed in terms of pFe for various ligands (10^{-2}M). The competing effect of H+ at low pH values and of OH at higher pH values explains that effective complexation is strongly dependent on pH. Mono-, di- and tridentate ligands (10^{-2}M) are not able to keep a 10^{-3}M Fe(III) in solution at higher pH values.

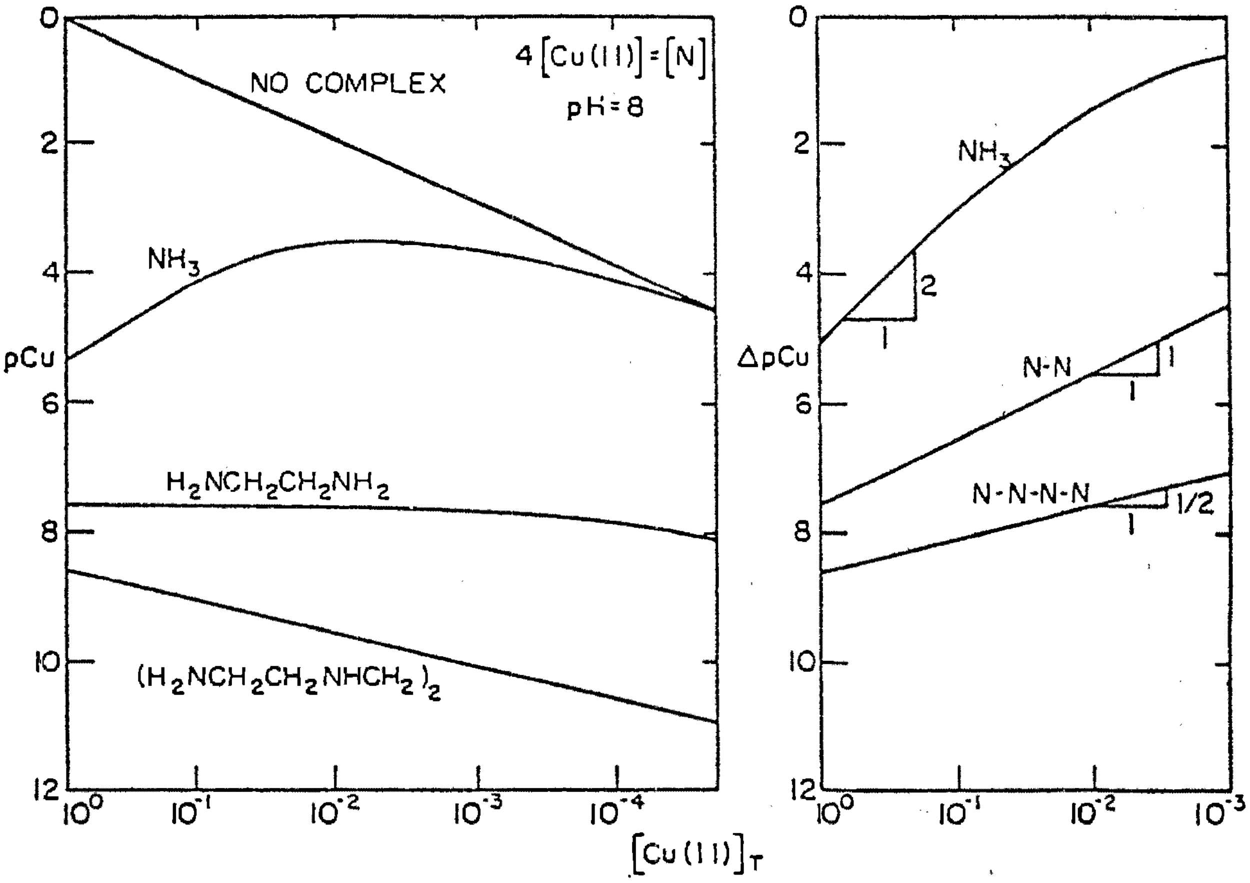

Figure VII-49

THE CHELATE EFFECT ON COMPLEX FORMATION OF Cu-aq^{2+} WITH MONODENTATE, BIDENTATE AND TETRADENTATE AMINES. pCu IS PLOTTED AS A FUNCTION OF CONCENTRATION IN THE LEFT-HAND DIAGRAM. IN THE RIGHT THE RELATIVE DEGREE OF COMPLEXATION AS MEASURED BY pCu AS A FUNCTION OF CONCENTRATION IS DEPICTED (69) increase in the Cu^{2+} species. Although other factors such as temperature and ionic activity affect solubilities, dilution will aid in the dissociation of the ammonia/copper complex.

Once this dissociation is accomplished, aqueous copper may be precipitated with hydroxides. Addition of lime ($Ca(OH_2)$) provides the necessary hydroxides and precipitation will occur at approximately pH = 10. Flocculation may be enhanced with addition of an organic polymer flocculating agent. Sedimentation may be followed by the passage of the supernatent through a granular media filter to insure effluent quality. Reduction of iron and copper to below the one mg/l level was accomplished using the overall treatment scheme in Figure VII-50.

Hydrochloric Acid Without Copper Complexer. Many times HCl (without copper complexer) is used in conjunction with ammoniated sodium bromate solutions, and will be incorporated with the treatment scheme for that solution. However, it may be used for removing heavy scales in boiler systems which do not contain copper, and thus the waste solution will not contain these relatively hard-to-break copper complexes. Effluent levels for iron and copper below one mg/l are expected as treatment levels attainable for metals will approach theoretical solubilities when pH is adjusted.

Figure VII-51 shows theoretical solubilities of a number of metals as a function of pH. From the diagram it may be seen that those metals found in waste hydrochloric acid cleaning solutions may be removed below 1 mg/l with pHs adjusted to approximately pH = 10. The adjustment of pH may be with the lime or sodium hydroxide, although sludge dewaterability is best when lime is used.

The treatment scheme employed for this waste stream is pH adjustment, sedimentaiton, and (possibly) polishing of supernatent with some form of filtration.

Hydrochloric Acid with Copper Complexer. Thiourea and Cutain II are two copper complexing agents which have been employed along with hydrochloric acid for the cleaning of boiler systems containing copper alloys. Successful treatment of these wastes, to obtain total metal residuals for iron and copper of below 1 mg/l each (61), involves breaking the copper complex and precipitating metal hydroxides.

Thiourea and Cutain II are multidentate ligands and, as such, are more stable than the ammonia-copper complex, ammonia being a monodentate ligand. Therefore, the same degree of dilution of these hydrochloric wastes to dissociate the complex is not as effective as it is for the degree of complexation.

In most cases, dilution occurs by combining acid stage wastes with rinse waters or other metal cleaning wastes. The effect of such dilution may be found in bench-scale test data contained in table VII-34. In this case, wastes were diluted and pH was adjusted to 9.5, where metals were precipitated and then the samples were filtered.

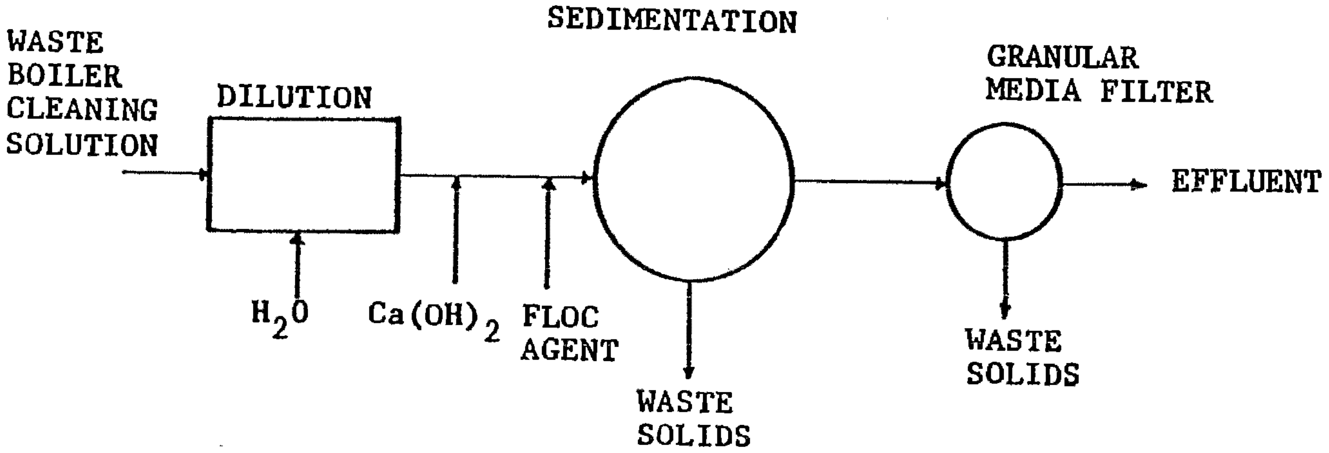
WASTE BOILER CLEANING SOLUTION
DILUTION
SEDIMENTATION
GRANULAR MEDIA FILTER
EFFLUENT
H_2O
$Ca(OH)_2$
FLOC AGENT
WASTE SOLIDS
WASTE SOLIDS

Figure VII-50

TREATMENT SCHEME FOR METALS REMOVAL BY PRECIPITATION FROM WASTE BOILER CLEANING SOLUTION

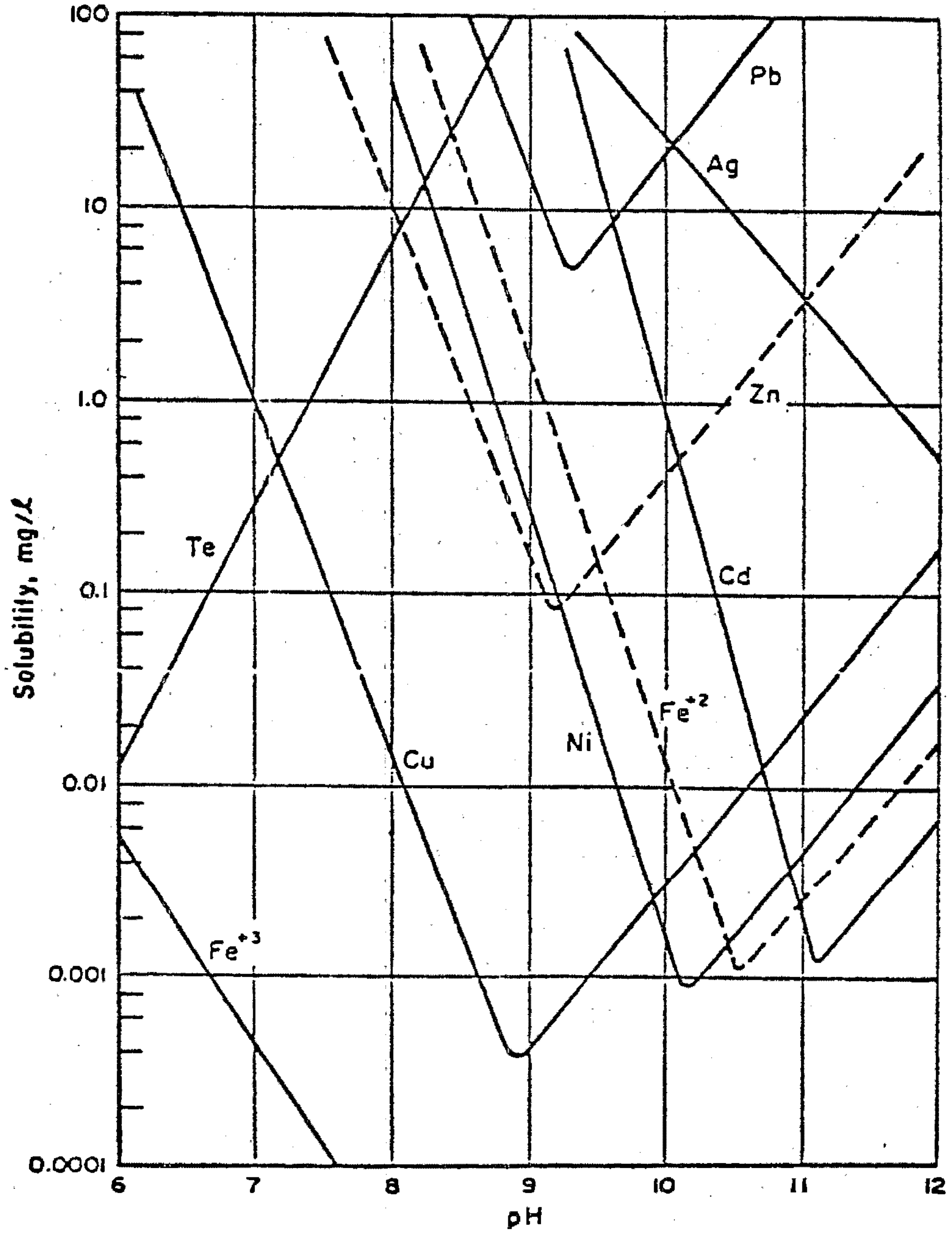

Figure VII-51

THEORETICAL SOLUBILITIES OF METAL IONS AS A FUNCTION OF pH (69)

Table VII-34

TREATMENT OF ACID CLEANING WASTEWATER SUMMARY OF JAR TESTS (61)

Concentration (mg/l)

Dissolved Metals	Before Treatment	After Treatment			
Zn	335	0.02	0.045	0.2	0.74
Ni	375	0.04	0.13	0.31	2.9
Cu	306	0.03	0.34	0.32	0.35
Fe	5,140	0.14	0.31	0.60	0.52
Mn	41	.01	.01	0.04	0.12
V	0.8	.1	.1	.1	0.5
Dilution prior to treatment	------	20:1	10:1	5:1	None

pH adjusted to 9.5 with lime

Source: Design Report Wastewater Treatment Facilities, New England Power Service Company

Another system using a similar treatment method also successfully removed metals below the 1 mg/l level. In addition, activated carbon has been used in order to absorb further the metal-complex species and toxic acid inhibitory chemicals (57).

Hydroxyacetic/Formic Acid. This chemical solution has found wide use in cleaning supercritical boilers because of its high iron pickup capabilities. The hydroxyacetic/formic acid solution chelates iron, and as such, is subject to dilution in order to dissociate the complex. Dilution with other plant wastes followed by oxidation (to change iron from the ferrous to the ferric state) and pH adjustment should yield an effluent with iron and copper below the 1 mg/l level.

Sulfuric Acid. Sulfuric acid, though used infrequently, may be employed on certain austenitic type alloys for the removal of heavy deposits. There are no complexing agents used in conjunction with this chemical, and thus treatment is believed to be similar to that of hydrochloric acid (without copper complexer).

Treatment Levels

Incineration (Evaporation). Disposal of waste boiler cleaning solutions by means of incineration (evaporation) has been tested for disposal capacities during a number of tests. Although metals were released to the environment, the organic content of the waste streams, along with obnoxious gases, were found to be nonexistent in the stack emissions. Problems could arise if stack controls are absent (57). The high temperature environment of the firebox area was shown to break down the organic content of the waste.

One means of measuring the impact of stack emissions is by estimating ground level concentrations with the Threshold Limit Values (TLV) for various components. TLV is defined as the time-weighed average exposure to an airborne contaminant for a period of eight hours a day, five days a week, over an individual's working lifetime, which will not produce adverse effects (56). Examination of various components of stack emissions for their TLV as fumes and dusts and mists, has been used by the Environmental Protection Agency for regulatory purposes. Such examination of incineration operations of waste boiler cleaning solutions has shown TLV of the various metals found in stack emissions to be below the allowable limits set by EPA.

These low TVL values are a result of heavy metals components of the waste solutions being retained in the boiler stack areas with efficiencies approaching 98 percent in some cases. However, even at this level, considerable amounts of heavy metals leave the stack as a result of incinerating waste boiler chemical cleaning solutions. If these emissions were distributed in a volume of water equal to that of the original waste volume, the effluent concentration (Equivalent Treated Effluent Concentration) would be orders of magnitude larger than present limits (1 mg/l). Table VII-35 illustrates the point for a number of incineration tests.

Table VII-35

EQUIVALENT TREATMENT OF INCINERATION TESTS

Waste Characteristics		Percent Retained	Equivalent Treated Effluent Concentration
Volume	90,850 liters		
Iron	727.27 kg	94	480 mg/l
Copper	163.64 kg	88	216 mg/l
Nickel	36.36 kg	90	40 mg/l
Volume	218,039 liters		
Iron	4142.74 kg	81	3456 mg/l
Copper	69.77 kg	94	19 mg/l

Ash Pond Treatment. The mechanisms believed to be incorporated by the chemical/physical nature of ash ponds for treatment of boiler cleaning wastes are the same as those which were found to be effective in physical/chemical treatment processes (i.e., dilution, oxidation, pH adjustment, precipitation). However, with the ash ponds, control of these variables may be difficult (if not impossible) and thus the question of attainment of effluent limitations. The level achievable in the ash pond must be equal to the original level in the ash pond prior to metal cleaning waste addition plus the value determined by dividing the effluent limitation (1 mg/l) by the dilution factor. Because of the accuracy and precision of the analytical methods, such demonstration may not be possible in some cases.

Physical/Chemical Treatment. Physical/chemical treatment methods have been used successfully to treat solutions of chelated metals. By employing various unit processes, it is possible to have control of all reactions needed to reduce the levels of heavy metals in waste boiler cleaning chemical solutions to below the one mg/l level. Table VII-36 shows the treatment levels of various treatment schemes.

COAL PILE AND CHEMICAL HANDLING RUNOFF

One treatment technology applicable to coal pile and chemical handling runoff is chemical precipitation/sedimentation. Chemical precipitation is discussed in the ash handling subsection of this section. Sedimentation is discussed in the 1974 Development Document (46).

Flue Gas Cleaning Discharges

In general flue gas cleaning processes employing wet scrubbing make maximum use of recycle of slurry water. Typical systems use thickeners which produce a high solids waste stream which is ponded and a supernatent which is recycled to the scrubber. The solids settling is typically accomplished in a pond where much of the water is retained as a part of the settled sludge. This water which overflows the pond is either recycled or discharged. While it was originally believed that most, if not all, such systems could operate in a closed-loop or zero discharge mode supporting data to confirm this is not available. The Agency plans to continue research into scrubber system discharges and their control.

Table VII-36

PHYSICAL/CHEMICAL TREATMENT PROCESSES AND EFFICIENCIES

Waste Type and Treatment Scheme	Parameter	Effluent Concentration (mg/l)
Hydrochloric acid with copper complexer		
Dilution + precipitation at pH = 1 sedimentation + filtration (61)	Fe	0.01
	Cu	0.14
	Zn	0.02
	Ni	0.04
	Mn	0.01
Ammoniated EDTA		
H_2S addition + precipitation at pH = 13 + sedimentation (57)	Fe	0.5
	Cu	0.61
Ammonical bromate + hydrochloric acid		
Dilution + precipitation at pH = 8.2 sedimentation + filtration (66)	Fe	*
	Cu	*
	Zn	*
	Ni	*

*Indicates that the value is below the detection limit.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

The cost, energy, and land requirements of the various treatment and control technologies described in section VII are presented in this section for typical steam electric powerplants. For most technologies, the costs are estimated for 25, 100, and 1,000 MW plants. For some of the fly ash handling technologies, the costs are estimated for 25, 100, 200, 350, 500, and 1,000 MW plants, in order to provide better information regarding the change in fly ash handling costs with decreasing plant size. Only summary information is provided in this section. A discussion of the non-water quality, environmental effects of the various treatment and control technologies is also provided in this section.

COOLING WATER

Once-Through Cooling Water Systems

The capital cost, operating and maintenance costs, energy requirements, and land requirements have been evaluated for the following technologies:

- Chlorine minimization,
- Dechlorination,
- Alternative oxidizing chemicals
  - bromine chloride
  - chlorine dioxide
  - ozone, and
- Non-oxidizing biocides.

Chlorine Minimization

Cost, Energy, and Land Requirements. Summary cost, energy and land requirements for chlorine minimization at both new and existing plants are presented in table VIII-1. The requirements for retrofitting an existing plant are identical to the requirements for a new plant.

Non-Water Quality Aspects. Chlorine minimization is not expected to have any non-water quality environmental effects.

Dechlorination

Costs, Energy, and Land Requirements. Summary cost, energy and land requirements at both new and existing plants for dechlorination of once-through cooling water systems are presented in table VIII-2. The requirements for retrofitting an existing plant are identical to the requirements for a new plant.

Table VIII-1

SUMMARY OF COST, ENERGY, AND LAND REQUIREMENTS FOR CHLORINE MINIMIZATION IN ONCE-THROUGH COOLING WATER SYSTEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	36,000	37,000	38,700
Operation and Maintenance ($/year)	9,200	9,100	8,500
Energy Requirements (kwh/year)	negligible	negligible	negligible
Land Requirements (acres)	none	none	none

Table VIII-2

SUMMARY OF COST, ENERGY, AND LAND REQUIREMENTS FOR DECHLORINATION IN ONCE-THROUGH COOLING WATER SYSEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	77,000	91,500	127,000
Operation and Maintenance ($/year)	20,000	36,400	84,900
Energy Requirements (kwh/year)	3.2×10^4	5.6×10^4	1.12×10^5
Land Requirements (acres)	none	none	none

Non-Water Quality Aspects. Dechlorination is not expected to have any non-water quality environmental effects.

Alternative Oxidizing Chemicals

Chlorine Dioxide. Summary cost, energy and land requirements for biofouling control with chlorine dioxide are presented in table VIII-3.

Non-Water Quality Aspects. Chlorine dioxide use in once-through cooling water systems is not expected to have any non-water quality environmental effects.

Bromine Chlorine. Summary cost, energy and land requirements for biofouling control with bromine chloride in once-through cooling water systems are presented in table VIII-4.

Non-Water Quality Aspects. Bromine chloride use in once-through cooling water systems is not expected to have any non-water quality environmental effects.

Ozone. Summary cost, energy and land requirements for the use of ozone as a biofouling control agent in once-through cooling water systems are presented in table VIII-5.

Non-Water Quality Aspects. The use of ozone in once-through cooling water systems is not expected to have any non-water quality environmental effects. An ozone destruction system is installed as part of the ozonation facility which prevents the release of ozone to the atmosphere.

Recirculating Cooling Water Systems

The capital cost, operational and maintenance costs, energy requirements, and land requirements have been evaluated for the following technologies:

- Dechlorination,
- Vapor Compression Distillation,
- Alternative Oxidizing Chemicals
    - chlorine dioxide
    - bromine chloride
    - ozone,
- Non-Oxidizing Biocides,
- Corrosion and Scaling Control, and
- Asbestos Cooling Tower Fill Replacement.

Table VIII-3

SUMMARY OF COST, ENERGY AND LAND REQUIREMENTS FOR BIOFOULING CONTROL WITH CHLORINE DIOXIDE IN ONCE-THROUGH COOLING WATER SYSTEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	19,000	19,400	20,200
Operation and Maintenance ($/year)	15,800	25,300	65,800
Energy Requirements (kwh/year)	1.24×10^4	1.24×10^4	1.24×10^4
Land Requirements (acres)	negligible	negligible	negligible

Table VIII-4

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR BIOFOULING CONTROL WITH BROMINE CHLORIDE IN ONCE-THROUGH COOLING WATER SYSTEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	51,600	52,600	95,200
Operation and Maintenance ($/year)	21,800	28,700	61,800
Energy Requirements (kwh/year)	1×10^4	1.3×10^4	1.81×10^4
Land Requirements (acres)	negligible	negligible	negligible

Table VIII-5

SUMMARY COST, ENERGY, AND LAND REQUIREMENTS FOR BIOFOULING CONTROL WITH OZONE IN ONCE-THROUGH COOLING WATER SYSEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	560,000	930,000	2,350,000
Operation and Maintenance ($/year)	12,500	16,200	31,600
Energy Requirements (kwh/year)	9.1×10^4	1.66×10^5	5.59×10^5
Land Requirements (acres)	negligible	negligible	negligible

Table VIII-6

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR DECHLORINATION OF RECIRCULATING COOLING SYSTEM DISCHARGE (BLOWDOWN)

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	54,200	54,200	57,200
Operation and Maintenance ($/year)	6,100	6,100	6,300
Energy Requirements (kwh/year)	1.6×10^3	1.6×10^3	1.6×10^3
Land Requirements (acres)	negligible	negligible	negligible

A discussion of the non-water quality aspects of each technology is also included.

Dechlorination

Cost, Energy, and Land Requirements. Summary cost, energy and land requirements for dechlorination at both new and existing plants using recirculating cooling water systems are presented in table VIII-6. The requirements for retrofitting an existing plant are identical to the requirements for a new plant.

Non-Water Quality Aspects. Dechlorination of cooling tower blowdown is not expected to result in any non-water quality environmental effects.

Vapor Compression Distillation

Cost, Energy, and Land Requirements. Summary cost, energy and land requirements for vapor compression distillation of cooling tower blowdown are presented in table VIII-7.

Non-Water Quality Aspects. Vapor compression distillation of cooling tower blowdown does not have any non-water quality environmental effects.

Alternative Oxidizing Chemicals

Chlorine Dioxide. Summary cost, energy and land requirements for the use of chlorine dioxide as a biofouling control agent in recirculating cooling water systems are presented in table VIII-8.

Non-Water Quality Aspects. The use of chlorine dioxide as a biofouling control agent at plants with recirculating systems is not expected to involve any non-water quality environmental effects.

Bromine Chloride. Summary cost, energy and land requirements for the use of bromine chloride as a biofouling control agent are presented in table VIII-9.

Non-Water Quality Aspects. The use of bromine chloride as a biofouling control agent at plants using recirculating cooling systems is not expected to have any non-water quality environmental effects.

Ozone. Summary cost, energy and land requirements for the use of ozone as a biofouling control agent in plants using recirculating cooling water systems are presented in table VIII-10.

Non-Water Quality Aspects. The use of ozone as a biofouling control agent at plants using recirculating cooling water systems is not expected to have any non-water quality environmental effects.

Table VIII-7

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR VAPOR COMPRESSION DISTILLATION OF COOLING TOWER BLOWDOWN

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	1,620,000	2,280,000	10,200,000
Operation and Maintenance ($/year)	46,500	51,000	124,000
Energy Requirements (kwh/year)	2.61×10^5	1.12×10^7	7.25×10^7
Land Requirements (acres)	0.12	1.0	5.8

Table VIII-8

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR BIOFOULING CONTROL WITH CHLORINE DIOXIDE IN RECIRCULATING COOLING SYSTEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	19,100	19,100	19,300
Operation and Maintenance ($/year)	8,500	9,500	18,500
Energy Requirements (kwh/year)	1.24×10^5	1.24×10^5	1.24×10^5
Land Requirements (acres)	negligible	negligible	negligible

Table VIII-9

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR BIOFOULING CONTROL WITH BROMINE CHLORIDE IN RECIRCULATING COOLING SYSTEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	36,600	36,900	52,300
Operation and Maintenance ($/year)	15,800	17,100	26,600
Energy Requirements (kwh/year)	$6.5x10^3$	$7.5x10^3$	$1.2x10^3$
Land Requirements (acres)	negligible	negligible	negligible

Table VIII-10

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR BIOFOULING CONTROL WITH OZONE IN RECIRCULATING COOLING SYSTEMS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	96,600	210,000	690,000
Operation and Maintenance ($/year)	7,800	9,000	13,800
Energy Requirements (kwh/year)	$1x10^4$	$2.2x10^4$	$1.06x10^4$
Land Requirements (acres)	negligible	negligible	negligible

Non-Oxidizing Biocides

Cost, Energy, and Land Requirements. As detailed in Section VII, the technology evaluated for the control of the discharge of priority pollutants contained in non-oxidizing biocide formulations is substitution. No additional cost, energy or land requirements are expected to be involved in the use of nonpriority pollutant mixtures as shown in table VIII-11.

Non-Water Quality Aspects. Switching to non-priority pollutant-containing, non-oxidizing biocides is not expected to have any non-water quality effects.

Corrosion and Scaling Control Chemicals

Cost, Energy, and Land Requirements. As detailed in Section VII, the technology evaluated for the control of the discharge of priority pollutants contained in scaling and corrosion control formulations is substitution. The additional cost, energy and land requirements incurred in switching from a priority pollutant-containing, scaling and corrosion control mixture to one that contains no priority pollutants are presented in table VIII-12.

Non-Water Quality Aspects. Switching to non-priority pollutant-containing, scale and corrosion control chemicals is not expected to have any non-water quality effects.

Replacement of Asbestos Cooling Tower Fill

The technology evaluated for the control of the discharge of asbestos in cooling tower blowdown is the replacement of the asbestos fill material with fill material of ceramic, PVC, or woods. The cost for asbestos cement fill replacement is extremely site-specific. Factors such as the current fill configuration, plant location, fill chosen for replacement, local labor wages and availability, proximity to appropriate asbestos fill disposal site and time available for fill replacement (cooling tower must be out of service) all affect the cost of fill replacement. The general range of the fill replacement costs can be estimated from repair work done by cooling tower manufacturers in the past. In one such case, the existing asbestos cement fill was damaged due to problems with the water chemistry of the recirculating water. This resulted in the leaching of calcium carbonate from the asbestos cement which brought about rapid fill deterioration. In another case, water freezing in the fill brought about serious damage. In both instances, complete fill replacement was necessary. Cost data from these two jobs is summarized in table VIII-13.

The numbers which appear in the table serve as only general guidelines and may vary as much as 50 percent due to site- specific conditions. The costs include the labor cost for removal of the old fill, the cost of the new fill material which was of PVC or other asbestos-free composition, and the labor cost to install the new fill. They do not include the cost of disposal of the old asbestos cement fill. In the

Table VIII-11

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR SWITCHING TO NON-PRIORITY POLLUTANT CONTAINING NON-OXIDIZING BIOCIDES

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	None	None	None
Operation and Maintenance ($/year)	The O&M cost (chemical purchase cost) of non-priority pollutant non-oxidizing biocides is less than for chlorinated phenols.		
Energy Requirements (kwh/year)	None	None	None
Land Requirements (acres)	None	None	None

Table VIII-12

SUMMARY COST, ENERGY AND LAND REQUIREMENTS FOR SWITCHING TO NON-PRIORITY POLLUTANT CONTAINING CORROSION AND SCALE CONTROL CHEMICALS

	Plant Size (MW)		
	25	100	1,000
Capital Cost ($)	None	None	None
Operation and Maintenance ($/year)	1,800	5,200	36,000
Energy Requirements (kwh/year)	negligible	negligible	negligible
Land Requirements (acres)	negligible	negligible	negligible

Table VIII-13

COOLING TOWER FILL REPLACEMENT COSTS

Size of Plant Cooling Tower Was Servicing (MW)	Type of Fuel	Cost of Materials (Million Dollars 1979)	Cost of Labor (Million Dollars 1979)	Total Cost (Million Dollars 1979)
700	Fossil	2	1	3
900	Nuclear	4	2	6

case of the 700- megawatt plant, some additional modifications to increase the thermal capacity of the tower were done at the time of the asbestos fill replacement. This brought the total cost of that project to about $3.5 million while effecting about a 15 percent increase in thermal capacity.

Labor costs were estimated to run between one-third and one-half of the total replacement cost. This cost will vary depending on how the labor force is scheduled (How much overtime is involved? How many workers are onsite simultaneously?). At the 700- megawatt fossil unit, it was estimated that the entire job could be completed in 10 weeks, with 120 to 200 workers on site simultaneously, working 10 hour days, 5 days per week. This works out to a total of about 75,000 man-hours. In actuality, the replacement work at the 700-megawatt plant is being done in two installments of 5 weeks each. It is possible to break fill replacement work down such that as little as one quarter of the work is done in one installment. This allows most of the fill replacement work to be done during normally scheduled plant outages thus reducing the otherwise enormous cost of plant shutdown for fill replacement purposes.

The operational costs of the tower may decrease upon asbestos fill replacement if the new fill and other tower modifications increased the tower efficiency. Yearly savings amounting from this are extremely site-specific.

The data indicate that costs in the range of $1-9 million can be expected for asbestos fill replacement allowing for the ±50 percent accuracy of the costs. Nuclear plants place a higher heat load on a cooling tower per megawatt of generated power when compared to fossil-fueled plants. As a result, the cost of fill replacement per unit of generated power will run higher for nuclear plants.

Non-Water Quality Aspects. The asbestos fill removed from the cooling tower may be considered a hazardous waste and require appropriate disposal.

ASH HANDLING

Fly Ash

Three treatment and control options for discharges from fly ash handling systems are costed in this section. They are:

1. Dry fly ash handling,

2. Partial recirculation of sluice water, and

3. Once-through sluicing with chemical precipitation.

Use of dry fly ash handling includes dry vacuum and dry pressure pneumatic conveying systems. Partial recirculation includes ponding and recycle of the sluice water with a continuous untreated discharge.

The once-through sluicing system involves sluicing the ash to a pond with the sluice water passing through a chemical precipitation system prior to discharge. The information presented for the fly ash handling systems includes capital costs, operating, and annual maintenance costs, energy requirements, and land requirements.

Dry Fly Ash Handling

Both pneumatic vacuum conveying and pneumatic pressure conveying were evaluated. Technical descriptions of these two systems can be found in chapter VII. The costs of each system were addressed separately and then were combined into a "composite" cost for a typical plant by consideration of the number of plants using each technology.

Dry fly ash handling capital costs are presented for these two technologies in terms of new plants and existing plants. Existing plants have an additional cost factor included for each case, the retrofit costs. The quantification of this factor was estimated because retrofit costs are very site specific. In all cases except the chemical precipitation system, the retrofit cost will equal the cost to install the system. The chemical precipitation retrofit cost was estimated to be 10 percent of the installation cost. This cost reflects a number of items: labor to take out existing equipment, labor to reroute existing piping, resulting downtime to install the new system, etc. New plants will not have to contend with this added cost. The engineering and contingency estimate was 20 percent of the installed system with retrofit cost.

Capital Costs for Dry Fly Ash Handling Systems. The capital costs for dry fly ash handling systems are presented in table VIII-14. All equipment, except for the dry storage silo, was costed for an ash conveying rate equal to twice the actual ash generating rate. The silo was sized based on a 72-hour storage capacity. A factor of 2.5 times the total equipment cost was used to estimate the total installed cost of the system. In addition, for existing plants, the retrofit cost was estimated as equal to the cost for installing the equipment. Engineering and contingencies were estimated as 20 percent of the installed system costs with retrofit penalties. Table VIII-14 presents costs which include all of these factors.

Operating and Maintenance (O&M) Costs. The nominal ash disposal cost assumed for dry fly ash handling was based on the assumption that the plants would have to dispose of the ash material regardless of any water discharge regulations and the difference in operating costs for disposal will be minimal. These O&M costs are presented in table VIII-15.

Energy Requirements. The energy requirements for either the vacuum or pressure systems involve, for the most part, the power requirements for the blowers. The range of power requirements for these blowers is from 38 KW to 180 KW at 150 TPH of fly ash. Other energy-consuming equipment included were the silo aerators, unloaders, vent return line

Table VIII-14

CAPITAL COSTS FOR DRY FLY ASH HANDLING SYSTEMS

	Plant Size (megawatts)					
	25	100	200	350	500	1000
Capital Costs (million dollars)						
Existing Plants	2.33	2.96	3.35	4.77	5.37	10.05
New Plants	1.45	1.90	2.16	3.14	3.54	6.76

Table VIII-15

ANNUAL OPERATING AND MAINTENANCE COST FOR DRY FLY ASH HANDLING SYSTEMS

	Plant Size (megawatts)					
	25	100	200	350	500	1000
Operation and Maintenance (million dollars/year)						
Existing Plants	0.347	0.373	0.405	0.459	0.509	0.690
New Plants	0.348	0.377	0.412	0.471	0.526	0.724

blowers, and silo heating coils. Table VIII-16 presents the annual energy requirements for the vacuum and pressure systems.

Land Requirements. The land requirements for the dry fly ash handling systems are given in table VIII-17. Land is required to contain the silo, blowers, and piping.

Non-Water Quality Aspects. The use of dry handling and disposal of fly ash over ponding will have a direct impact from the standpoint of solid wastes disposal. Landfilling of the ash material must be conducted in an environmentally sound manner. If proper landfill operations are used, the potential problems of fugitive dust and leaching of ash into groundwater can be contained.

Partial Recirculating and Chemical Precipitation of Fly Ash

The technologies which are addressed in these two categories are (1) ponding of the fly ash with partial recycle of the sluice water, and (2) ponding of the fly ash with total discharge of sluice water after chemical precipitation. The partial recirculating system includes the addition of a clear pond and a recycle line back to the fly ash sluice pumps. The second system includes the addition of a chemical precipitation system. The costs and other requirements for these two systems were addressed in the same manner as for the fly ash handling systems. Similar assumptions were utilized for addressing new and existing plants, pulverized and cyclone-fired boilers.

Capital Costs. The capital costs for the wet fly ash handling systems are presented in table VIII-18. The equipment upon which the partial recirculation capital costs were based are a clear pond, piping, and pumps. The once-through sluicing equipment is that associated with the chemical precipitation system. Further description of these systems can be found in chapter VII.

Operating and Maintenance Costs. The O&M cost assumptions for the once-through system were solely based on the chemical precipitation system operation. These O&M costs are presented in table VIII-19.

Energy Requirements. The energy requirements for these two systems are presented in table VIII-20. The energy requirements for partial recycle/fly ash were based on the energy used by the recycle pumps. The wet once-through system requirements were based on those for the chemical precipitation system.

Land Requirements. The land requirements for these two systems are presented in table VIII-21. For the partial recirculating system, the land requirement was based on a clear pond and piping from the pond to the sluice pumps. For the wet once-through system, only the land needed for the chemical precipitation system was estimated.

Non-Water Quality Aspects. The use of partial recirculation is not expected to have any impacts over current operations. The use of chemical precipitation will result in a lime sludge which must be

Table VIII-16

ENERGY REQUIREMENTS FOR DRY FLY ASH HANDLING SYSTEMS

	Plant Size (megawatts)					
	25	100	200	350	500	1000
Energy Requirements (million kilowatt-hours/year)						
Existing Plants	0.340	0.340	0.340	0.340	0.340	0.916
New Plants	0.340	0.340	0.340	0.340	0.340	0.980

Table VIII-17

LAND REQUIREMENTS FOR DRY FLY ASH HANDLING SYSTEMS

	Plant Size (megawatts)					
	25	100	200	350	500	1000
Land Requirements (acres)						
Existing Plants	0.75	1.0	1.2	1.4	1.5	2.0
New Plants	0.75	1.0	1.2	1.4	1.5	2.0

Table VIII-18

CAPITAL COSTS FOR PARTIAL RECIRCULATING AND CHEMICAL PRECIPITATION OF ONCE-THROUGH FLY ASH SLUICING SYSTEMS

(million dollars)

1. Partial Recirculation

	Plant Capacity (MW)		
	25	100	1000
Existing	0.845	0.881	1.700
New	0.528	0.553	1.120

2. Once-Through Sluicing with Chemical Precipitation

	Plant Capacity (MW)					
	25	100	200	350	500	1000
Existing	0.369	0.840	1.272	1.781	2.099	3.31
New	0.348	0.792	1.200	1.680	1.980	3.12

Table VIII-19

OPERATING AND MAINTENANCE COSTS FOR PARTIAL RECYCLE AND CHEMICAL PRECIPITATION OF ONCE-THROUGH FLY ASH SLUICING SYSTEMS

(million dollars/year)

1. Partial Recirculation

	Plant Capacity (MW)		
	25	100	1000
Existing	0.331	0.331	0.332
New	0.331	0.331	0.331

2. Once-Through Sluicing With Chemical Precipitation

	Plant Capacity (MW)					
	25	100	200	350	500	1000
Existing	0.105	0.185	0.326	0.510	0.693	1.12
New	0.105	0.185	0.326	0.510	0.693	1.12

Table VIII-20

ENERGY REQUIREMENTS FOR PARTIAL RECIRCULATING AND WET CHEMICAL PRECIPITATION OF ONCE-THROUGH FLY ASH SLUICING SYSTEMS

(million kilowatt-hours/year)

1. Partial Recirculation

	Plant Capacity (MW)		
	25	100	1000
Existing	0.160	0.630	8.13
New	0.160	0.680	8.94

2. Once-Through Sluicing With Chemical Precipitation

	Plant Capacity (MW)					
	25	100	200	350	500	1000
Existing	0.498	0.566	0.641	0.753	0.857	1.09
New	0.498	0.566	0.641	0.753	0.857	1.09

Table VIII-21

LAND REQUIREMENTS FOR PARTIAL RECIRCULATING AND CHEMICAL PRECIPITATION OF ONCE-THROUGH FLY ASH HANDLING SYSTEMS

(acres)

1. Partial Recirculation

	Plant Capacity (MW)		
	25	100	1000
Existing	6.1	6.4	10.32
New	6.1	6.4	10.32

2. Once-Through Sluicing With Chemical Precipitation

	Plant Capacity (MW)					
	25	100	200	350	500	1000
Existing	0.3	0.4	0.4	0.5	0.5	0.7
New	0.3	0.4	0.4	0.5	0.5	0.7

Table VIII-22

CAPITAL COSTS FOR COMPLETE RECYCLE BOTTOM ASH HANDLING SYSTEM

(million dollars)

	Plant Capacity (MW)		
System	25	100	1000
Complete Recycle with Softening			
Existing	1.431	1.569	2.508
New	0.882	0.967	1.381

disposed of in a properly operated landfill. Proper landfill operation should insure against the possibility of leaching of material in the sludge which may otherwise enter groundwater.

Bottom Ash

The discussion of bottom ash handling systems will include individual presentations of capital costs, operating and maintenance annual costs, energy requirements, and land requirements for 25, 100, and 1,000 MW 'typical' plants. The specific technologies associated with bottom ash handling are represented in the contexts of complete recycle and partial recycle. The concept of complete recycle, as discussed in chapter VII, involves the elimination of any direct discharge from the sluice system.

Partial recycle allows for a continuous direct discharge from the sluice system with the remainder of the sluice stream returned to the main sluice pumps.

Complete Recycle

The technologies which are addressed in the complete recycle category include hydrobin/dewatering bin systems, and ponding with recycle. Both technologies in this case were considered in terms of complete recycle by using slip stream softening. Costs for each of these technologies were composited in order to generate typical costs for a given plant installing complete recycle bottom ash handling. Both existing and new facilities are addressed. Existing plants have an additional cost factor included for each case, the retrofit costs. In all cases, the retrofit cost was assumed to equal the cost to install the system. This retrofit cost reflects a number of items: labor to take out existing equipment, labor to reroute existing piping, resulting downtime to install the new system, etc. New plants will not have to contend with this added cost.

Capital Cost. The capital costs are presented in table VIII-22 for the bottom ash handling systems which are considered for complete recycle. The dewatering bins system/slip stream softening capital costs were the summation of the dewatering bin system and slip stream softening system costs. The slip stream softening system cost was based on treatment of 10 percent of the ash sluicing stream. For existing plants, an installation factor was considered to yield an installed system cost of 2.5 times the equipment cost.

The retrofit penalty was considered to be equal to the cost of installation; the engineering and contingency were estimated to be 20 percent of the installed system with retrofit penalty. New plants, of course, were not penalized for retrofit costs.

The second major system that was costed for a complete recycle scenario was ponding with recycle. The pond was assumed to be built 1 mile from the bottom ash sluice pumps. The slip stream softening system was assumed to treat 10 percent of the recycle stream and used the same equipment as presented above.

Operating and Maintenance Costs. The maintenance materials criteria were different for hydrobin systems and recycle systems. For hydrobin systems, the maintenance materials cost was estimated to be 2 percent of the equipment cost annually. For recycle, this annual cost was assumed to be 1 percent of equipment cost. The slip stream softening O&M costs were calculated based on the amount of sluice water treated. A nominal ash disposal cost was assumed for the dewatering bin systems; this cost was $1 per ton of bottom ash produced. This cost was based on the assumption that the plants would have to dispose of the ash material regardless of any water discharge regulations and the difference in operating costs for disposal will be minimal. Costs for both alternative systems were composited in order to generate typical costs for a given plant installing complete recycle bottom ash handling. The operation and maintenance costs are presented in table VIII-23.

Energy Requirements. The estimation of energy requirements was made in terms of annual consumption of electricity. The requirements for the dewatering bin systems were based on the pumping requirements. Energy requirements for both systems were composited into typical energy requirements for a given plant installing complete recycle bottom ash handling. The energy requirements are presented in table VIII-24.

Land Requirements. The land requirements for a complete recycle system are given in table VIII-25. For recirculating systems, land requirements were for the clear pond and piping from the clear pond to the bottom ash hoppers. For the dewatering bin systems, land is required for the bins, tanks and pumps and piping.

Non-Water Quality Aspects. The use of complete recycle may require chemical softening of the recycle water. This would result in a lime sludge which must be disposed of in a landfill. If proper landfill operations are used, the potential problem of leaching into groundwater can be contained.

Partial Recycle

The technologies which are addressed for bottom ash partial recycle systems are the same basically as those presented for complete recycle. The difference between the two scenarios is that the partial recycle bottom ash handling systems will not include a slip stream softening system.

The costs and other requirements were addressed in the same manner as for the complete recycle systems. Similar assumptions were utilized for addressing new and existing plants, pulverized and cyclone-fired boilers.

Table VIII-23

OPERATING AND MAINTENANCE COSTS FOR COMPLETE RECYCLE BOTTOM ASH HANDLING SYSTEM

(million dollars/year)

System	Plant Capacity (MW) 25	 100	 1000
Complete Recycle with Softening			
Existing	0.440	0.445	0.561
New	0.440	0.445	0.535

Table VIII-24

ENERGY REQUIREMENTS FOR COMPLETE RECYCLE BOTTOM ASH HANDLING SYSTEM

(kwh/year)

System	Plant Capacity (MW) 25	 100	 1000
Complete Recycle with Softening			
Existing	1.19×10^5	1.96×10^5	1.48×10^6
New	1.12×10^5	1.53×10^5	1.04×10^6

Table VIII-25

LAND REQUIREMENTS FOR COMPLETE RECYCLE BOTTOM ASH HANDLING SYSTEM

(acres)

System	Plant Capacity (MW) 25	100	1000
Complete Recycle			
Existing	3.55	3.8	5.4
New	3.55	3.8	5.4

Table VIII-26

CAPITAL COSTS FOR PARTIAL RECYCLE BOTTOM ASH HANDLING SYSTEM

(million dollars)

System	Plant Capacity (MW) 25	100	1000
Partial Recycle			
Existing	1.260	1.262	1.59
New	0.787	0.814	1.41

Capital Costs. The capital costs for the partial recycle systems are presented in table VIII-26. The equipment upon which these costs are based, i.e., dewatering bins without slip stream softening and recirculation without slip stream softening, may be found in the capital cost discussion of complete recycle systems.

Operating and Maintenance Costs. The O&M annual costs estimated for the partial recycle systems were established based on the same assumptions as for the complete recycle technologies. The slip stream softening O&M costs were omitted in the partial recycle cases. Table VIII-27 presents the O&M cost requirements for the partial recycle systems.

Energy Requirements. The energy requirements estimated for the partial recycle systems were established based on the same assumptions as for the complete recycle technologies. The slip stream softening energy requirments were omitted in the partial recycle cases. Table VIII-28 presents the annual energy requirements for the partial recycle systems.

Land Requirements. The land requirements estimated for the partial recycle systems were established based on the same assumption as for the complete recycle technologies. The slip stream softening land requirements were omitted in the partial recycle cases. Table VIII-29 presents the land requirements for the partial recycle systems.

Non-Water Quality Aspects. No nonwater quality impacts are anticipated as a result of requiring partial recirculation of sluice water.

Low Volume-Wastes

The technology costed for the treatment of low-volume wastes is vapor compression evaporation (VCE). The sources of these wastes tend to be intermittent and batch in nature, requiring a basin to equalize the flow prior to treatment. The cost for diked impoundment of the water, assuming $10,000 per impoundment acre, is shown in table VIII-30.

The installed battery limits costs for the VCE system are shown in table VIII-31. The system life is expected to be 30 years. The materials of construction for the system are titanium, stainless steel and special steel alloys.

The technologies costed for the disposal brine (evaporator bottoms) are evaporation ponds and spray drying. The capital and operation and maintenance costs for a typical diked clay-lined pond for 20 inches per year net evaporation are presented in table VIII-32. These costs are based on the following items:

- dirt and excavation cost--$20,000 per acre, and
- clay costs and installation--$20,000 per acre.

Table VIII-27

OPERATING AND MAINTENANCE COSTS FOR PARTIAL RECYCLE BOTTOM ASH HANDLING SYSTEM

(million dollars/year)

System	Plant Capacity (MW) 25	100	1000
Partial Recycle			
Existing	0.355	0.359	0.421
New	0.355	0.357	0.395

Table VIII-28

ANNUAL ENERGY REQUIREMENTS FOR PARTIAL RECYCLE BOTTOM ASH HANDLING SYSTEM

(kwh/year)

System	Plant Capacity (MW) 25	100	1000
Partial Recycle			
Existing	0.99×10^5	1.72×10^5	1.42×10^6
New	0.92×10^5	1.30×10^5	9.80×10^5

Table VIII-29

LAND REQUIREMENTS FOR PARTIAL RECYCLE BOTTOM ASH HANDLING SYSTEMS

(acres)

System	Plant Capacity (MW) 25	 100	 1000
Partial Recycle			
Existing	3.55	3.8	5.4
New	3.55	3.8	5.4

Table VIII-30

IMPOUNDMENT COST

	Plant Size (MW) 25	 100	 1000
Capital Cost ($)	4,200	8,400	12,000
Operation and Maintenace ($/year)	negligible	negligible	negligible
Land Requirements (acres)	0.35	0.7	1.0

Table VIII-31

COST OF VAPOR COMPRESSION EVAPORATION SYSTEM

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)[a]	1,140,000	2,040,000	2,880,000
Operation and Maintenance[b] ($/year)	25,000	32,000	39,000
Energy Requirements (kwh/year)	1.6×10^6	3.2×10^6	4.8×10^6
Land Requirements (ft^2)	4,000	4,000	4,000

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a - The capital costs include 10 percent for engineering and 10 percent for contingencies.

b - The operation and maintenance costs assume continuous operation at a 55 capacity factor.

Table VIII-32

COST OF EVAPORATION PONDING

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost[a] ($)	129,000	259,000	388,800
Operation and Maintenance ($/year)	3,240	6,480	9,720
Energy Requirement (kwh/year)	neglibile	negligible	negligible
Land Requirements (acres)	2.7	5.4	8.1

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a - Cost of land not included.

The capital and O&M costs as well as energy and land requirements are presented in table VIII-33.

COAL PILE RUNOFF

For the treatment of coal pile runoff, two treatment and discharge options are presented:

Option 1--equalization, pH adjustment, settling, and
Option 2--equalization, chemical precipitation treatment,
settling, pH adjustment.

The costs of Option 1 include impoundment (for equalization), a lime feed system and mixing tanks for pH adjustment, and a clarifier for settling.

The costs for the impoundment area include diking and containment around each coal pile and associated sumps and pumps and piping from runoff areas to impoundment area. The costs for land are not included. The cost of impoundment for pH adjustment is shown in table VIII-34.

The lime feed system employed for pH adjustment includes a storage silo, slaker, feeder, and lime slurry storage tank as well as instrumentation, electrical connections, piping and controls. The capital and O&M costs for pH adjustment are shown in table VIII-35. Rubber-lined steel mixing tanks are employed to accommodate wastes with a pH of less than 6. The capital and O&M costs as well as energy and land requirements for mixing are presented in table VIII-36.

The clarifier is assumed to have a 3-hour retention time. The costs of clarification are presented in table VIII-37.

The costs of Option 2 include impoundment for equilization, a lime feed system, mixing tank, and polymer feed system for chemical precipitation, a clarifier for settling and an acid feeder and mixing tank to readjust the pH within the range of 6 to 9. The equipment and system design, with the exception of the polymer feeder, acid feeder and final mixing tank, is essentially the same as for Option 1.

The costs for the impoundment area are the same as for Option 1 (refer to table VIII-34).

The costs for the lime feed system are presented in table VIII-38. The components of this sysem are the same as those for Option 1.

Two tanks are required for Option 2; one for precipitation and another for final pH adjustment with acid. The cost of mixing is therefore twice that of Option 1 (refer to table VIII-36).

The polymer feed system includes storage hoppers, chemical feeder, solution tanks, solution pumps, interconnecting piping, electrical

Table VIII-33

COST OF SPRAY DRYING SYSTEM

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	600,000	648,000	744,000
Operation and Maintenance ($/year)	25,000	25,800	27,400
Energy Requirements (kwh/yr)	3.7×10^6	7.4×10^6	1.0×10^7
Land Requirements (ft^2)	800	800	800

Table VIII-34

COST OF IMPOUNDMENT FOR COAL PILE RUNOFF

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	4,500	4,500	9,000
Operation and Maintenance ($)	negligible	negligible	negligible

Table VIII-35

COST OF LIME FEED SYSTEM

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	91,200	168,000	258,000
Operation and Maintenance ($/year)	3,800	7,000	11,500
Energy Requirements (kwh/yr)	3.6×10^4	3.6×10^4	3.6×10^4
Land Requirements (ft^2)	5,000	5,000	5,000

Table VIII-36

COST OF MIXING EQUIPMENT

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	43,200	60,000	76,800
Operation and Maintenance ($/year)	1,500	1,600	1,700
Energy Requirements (kwh/yr)	1.3×10^3	3.3×10^3	6.5×10^3
Land Requirements (ft^2)	2,000	2,000	2,000

Table VIII-37

CLARIFICATION

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	120,000	156,000	186,000
Operation and Maintenance ($/year)	2,100	2,400	2,700
Energy Requirements (kwh/yr)	1.3×10^3	3.3×10^3	6.5×10^3
Land Requirements (acres)	0.07	0.11	0.16

Table VIII-38

COST FOR LIME FEED SYSTEM

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	91,200	168,000	258,000
Operation and Maintenance ($/year)	3,800	7,000	11,500
Energy Requirements (kwh/yr)	3.6×10^4	3.6×10^4	3.6×10^4
Land Requirements (ft^2)	5,000	5,000	5,000

connections and instrumentation. The costs of the polymer feed system are shown in table VIII-39.

The cost of clarification is identical to that of Option 1 (refer to table VIII-37).

Option 2 requires the use of an acid addition system to readjust the pH within the range of 6 to 9. The components of this system include a lined acid storage tank, two feed pumps, an acid pH control loop, and associated piping, electrical connections and instrumentation. The specific costs as well as energy and land requirements of the acid feed system are presented in table VIII-40.

Table VIII-39

COST OF POLYMER FEED SYSTEM

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	1,200	1,500	1,500
Operation and Maintenance ($/year)	1,100	1,100	1,100
Energy Requirements (kwh/yr)	$2.2x10^3$	$2.2x10^3$	$2.2x10^3$
Land Requirements (ft^2)	100	100	100

Table VIII-40

COST OF ACID FEED SYSTEM

	Plant Size (MW)		
	25	100	1000
Installed Capital Cost ($)	22,800	36,000	51,600
Operation and Maintenance ($/year)	1,500	1,700	2,000
Energy Requirements (kwh/yr)	75	180	360
Land Requirements (ft^2)	100	100	100

SECTION IX

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE GUIDELINES AND LIMITATIONS, AND NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS

The technical information presented in the previous sections was evaluated in light of the Water Pollution Control Act (P.L. 92-500) as amended and the Settlement Agreement in NRDC vs. Train 8 ERC 2120 (D.D.C. 1976), modified at 12 ERC 1833 (D.D.C. 1976). The Agency has determined, from the list of technology options, the best available technology economically achievable and new source performance standards for the following waste streams:

1. Once-Through Cooling Water

2. Recirculating Cooling Water Blowdown

3. Fly Ash Transport Water

4. Bottom Ash Transport Water

5. Metal Cleaning Wastes

6. Low Volume Wastes

7. Coal Pile Runoff

8. Ash Pile, Chemical Handling Area and Construction Area Runoff

9. Flue Gas Scrubber Discharge

The BATEA guidelines and limitations and NSPS are summarized in the following discussion which includes a brief description of the technology based limitations, an estimate of the uncontrolled pollutant loadings associated with the waste streams, and an estimate of the quantity of pollutants removed following application of BAT or NSPS.

Rationale for Proposal by Waste Streams

A. Once-Through Cooling Water

1. Pollutants Present

The Agency detected several pollutants in once-through cooling water discharges. Table VI-1 lists those pollutants detected at least once in greater concentrations in the effluent than in the influent. The pollutants present as a result of plant operation are copper, chromium, nickel, zinc, bromoform, chloroform, chlorodibromonethane, and total residual chlorine (TRC).

2. Need to control TRC

In general, chlorine is a strong oxidizing agent with a high solubility in water. Numerous reports are available that document the toxicity of chlorine and its byproducts to aquatic organisms. Chlorine in water may be present as free available chlorine (hypochlorous acid or hypochlorite ion) or combined residual chlorine (mono-, di-, and tri-chloramines) or other chlorine derivatives. Studies have shown that the toxicity to aquatic life is dependent on the concentration of total residual chlorine (TRC) remaining in the water, including both free available and combined residual chlorine, as well as the duration of contact. In estuarine/marine environments, brominated compounds are formed instead. The term "residual oxidants" is more appropriate than "residual chlorine" in such cases. Of about 550 plants with once-through cooling, EPA estimates that 335 use chlorine for biofouling control.

3. Available technologies and techniques

Because of current requirements in Part 423, and because of state and local requirements, many power plants already are making efforts to reduce their TRC discharges. The principal ways in which to curtail or eliminate TRC discharges include the following:

(a) no biocides --

The intake water quality at many plants is such that condenser biofouling is not a problem. Characteristics of this type of intake water include high turbidity, low dissolved oxygen or low temperatures. Currently, 40 percent of the plants with once-through cooling water do not chlorinate.

(b) use of alternative biocides to chlorine --

Some plants with biofouling problems use other biocides than chlorine. The alternative biocides include chlorine bromide, chlorine dioxide and ozone.

(c) chlorine minimization --

In the past, caution has dictated the liberal chlorination of condenser tubes. Plant operators are discovering, however, that by following careful operating, monitoring, and maintenance procedures, they can significantly reduce the use of chlorine without impeding effective biofouling control.

In essence, "chlorine minimization" is nothing more than a program designed to assure the most efficient use of chlorine and reduce the amount of TRC discharged. Such a program requires plant personnel to conduct a number of tests to determine the minimum amount of chlorine necessary to control biofouling. Chlorination practices then can be adjusted in accordance with the test results. Continued monitoring and inspection of the condensers on a periodic basis is also required.

Many power plants undergoing some form of chlorine minimization program find that they do not need biofouling control at all; others find that their current chlorine doses can be reduced significantly.

(d) dechlorination --

Some plants have installed chemical treatment devices that remove a significant amount of TRC from the cooling water before it is discharged from the plant. Most of these dechlorination devices use sulfur dioxide or sodium thiosulfate to accomplish TRC reduction. The reaction products, if sulfur dioxide is used, are sulfate ions, chloride ions and ammonium bisulfate. Each is present in low concentrations and have been shown to have insignificant pH and dissolved oxygen shift effect. This technology has been demonstrated to be effective both in fresh and salt water media. This technology reduces TRC to less than 0.14 mg/l at any time (instantaneous maximum).

(e) mechanical antifouling devices --

Some plants use mechanical devices, either with chlorine or in place of chlorine, to control biofouling. Two types of on-line mechanical devices are used. One method uses sponge rubber balls of slightly larger diameter than the inside diameter of the tubes to be cleaned. The balls are fed to the inlet of the exchanger, forced through the tubes under water pressure, removed at the downstream side of the heat exchanger, and recycled. A second method uses brushes which are installed in each tube. Movement of the brushes is induced by periodic changes in the direction of the cooling water flow.

4. Proposed Regulation

a. BAT

The Agency is proposing to prohibit the discharge of total residual chlorine (TRC); however, power plants that demonstrate a need for chlorine to control condenser biofouling may discharge the minimum amount of TRC necessary (chlorine minimization program). In no event may a TRC discharge exceed 0.14 mg/l maximum concentration at the point of discharge. Moreover, TRC may not be discharged from any discharge point for more than two hours per day unless the plant shows that chlorination for a longer period is required for crustacean control. The current Part 423 provision prohibiting simultaneous chlorination of several units would be deleted. This provision is already incorporated into the chlorine minimization requirements.

Section 301(b)(2)(A) of the Act requires the Agency to develop limitations that will result in reasonable further progress towards eliminating all pollutant discharges. This section states that BAT limitations must prohibit pollutant discharges if the Agency finds this technologically and economically achievable.

The Agency has determined that at many plants, a prohibition against TRC discharges is technologically and economically achievable. As noted earlier, about 40 percent of existing power plants with once-through cooling do not chlorinate at all. Moreover, the Agency believes that some plants now using chlorine could discontinue it without adverse effect.

Many plants, however, must use chlorine or other means to control biofouling because of the nature of their intake water. For such plants, a total prohibition against TRC discharges may be neither technologically nor economically achievable. Mechanical anti-fouling devices are expensive to backfit, and are not always adequate substitutes for chlorine. There is insufficient data to demonstrate that the alternative biocides can substitute for chlorine under all cases, or if they are more or less environmentally acceptable on a national basis. This is not to say that the use of alternative biocides and/or mechanical systems might not be appropriate in some cases.

Dechlorination has been demonstrated to be effective from both technical and economic standpoints. While dechlorination significantly reduces the amount of TRC discharged, it does not eliminate it.

Accordingly, the Agency has structured the proposed TRC regulation in two basic parts. First, the proposed regulation contains a general prohibition against TRC discharges. This is BAT for the many plants that do not need chlorine for biofouling control. Second, the proposed regulation requires that any plant which must control biofouling must use only the minimum amount of chlorine demonstrated to be necessary at that plant (chlorine minimization).

Plants needing to use chlorine to control biofouling in their once-through cooling water must demonstrate to the NPDES permit-writer, through the chlorine minimization study set forth in Appendix A of the proposed regulations, how much chlorination is actually necessary at the plant. Based on this study, the permit writer establishes a BAT limitation for that plant (in terms of a TRC concentration level (mg/l) as well as limits on the duration and frequency of chlorine added) reflecting the minimum amount of chlorination necessary to control biofouling. The limitations may vary seasonally or vary with intake water temperature.

The proposed regulation specifies that in no event may a TRC limitation exceed 0.14 mg/l concentration at the point of discharge. The Agency believes that many plants can achieve this limitation merely by following the minimization program. In the event a plant cannot meet this limit with minimization only, the plant could meet the limitation by adding a dechlorination system. Thus, the proposed BAT for plants that must chlorinate requires a minimization program in all cases, and may require dechlorination in some.

The Agency considered the option of merely requiring minimization without specifying a maximum TRC concentration level. Under this option, no plant would be required by BAT to dechlorinate. The Agency's conclusion, however, is that this approach would impede reasonable further progress toward the elimination of TRC discharges throughout the nation because some plants would be allowed to discharge TRC at concentrations much greater than those which can be achieved by a technology (dechlorination) that is both technically and economically available.

Another option was to specify a maximum TRC concentration level (based upon dechlorination technology for plants that must chlorinate) without first requiring that the plants minimize their use of chlorine. The Agency has rejected this option because many plants have the ability with economically and technologically available procedures (chlorine minimization) to discharge a lower maximum TRC concentration level than is generally achievable on a national basis by dechlorination (maximum of 0.14 mg/l). Further, the chlorine minimization program is environmentally advantageous in that it always reduces, and in some cases eliminates, the discharge of chlorine. Further, those plants that will be required to dechlorinate after the chlorine minimization program will use less dechlorination chemicals.

The Agency believes that the proposed scheme best follows the mandate of §301(b)(2)(A), which is that BAT should be no discharge unless it is not technogically or economically feasible. The Agency's scheme assures that there will be no TRC discharge at plants where this is technologically and economically feasible, and limits discharges at other plants to the maximum degree technologically and economically feasible.

The Agency is also proposing to limit TRC discharges from plants that must chlorinate to no more than two hours per day unless plant personnel can demonstrate that discharges for longer periods are necessary for crustacean control. This limitation is essentially the same as that which is already in effect for free available chlorine.

Finally, the Agency is proposing to relax current Part 423 in one respect. The current BAT regulation prohibits simultaneous chlorine discharges from more than one unit at any plant, even if each unit is meeting the maximum concentration and hours-per-day limitations. The Agency is proposing to eliminate this restriction because plants with multiple units may not be able to comply with the one unit at a time restriction. The current Part 423 provision prohibiting simultaneous chlorination of several units (unless a demonstration of need is made) would be deleted. This provision is already incorporated into the chlorine minimization requirements.

This change is necessary because the proposed discharge limitations are more stringent than BPT and adequate biofouling control for multi-unit plants, in some cases, may require multi-unit chlorination. It should be noted that BPT provides for exemption from the "one-unit-at-a-time" requirement if the need for multi-unit chlorination can be demonstrated. The minimization program required by this proposed regulation is equivalent to the demonstration of need required under BPT.

b. NSPS

The proposed NSPS is the same as the proposed BAT.

Section 306(a)(1) directs the Agency to set a NSPS which prohibits pollutant discharges "where practicable." The Agency must also consider costs. §306(b)(1)(B). For the same reasons discussed in part 4a above, practical considerations and high costs are the reasons for not imposing an across-the-board prohibition on TRC discharges. The Agency is accordingly proposing to make NSPS equivalent to BAT.

c. PSES

The proposed PSES do not restrict the discharge of any pollutants from this wastewater source.

For PSES, the Agency is proposing no limitations on TRC because no plants currently discharge their once-through cooling water to POTW's. In addition, TRC dissipates in the POTW system.

d. PSNS

For PSNS, EPA is proposing no limitations on TRC or any other pollutants. Because of the massive flows, it is unlikely that new plants will discharge to POTW's. In addition, the TRC dissipates in the POTW system.

B. Cooling Tower Blowdown

1. Pollutants Present

Several pollutants detected in cooling tower blowdown discharges were attributed entirely to their presence in the intake water. The sampling data show that the following pollutants are being discharged as a result of power plant operations: copper, nickel, zinc, asbestos, benzene, chloroform, 2,4-dichlorophenol, total phenolics and TRC. Table VI-1 lists those pollutants that were detected at least once in the EPA data base in greater concentrations in the effluent than in the influent.

2. Need to control TRC and other chemicals added for cooling tower maintenance

Chlorine is commonly added to cooling water to inhibit organism growth in both the tower and the condenser. Of about 300 plants with recirculating cooling systems, approximately 75 percent of these plants use chlorine. The need to control TRC discharges was covered in the previous discussion on once-through cooling water. In addition to chlorine, other chemicals may be added to control scaling, corrosion, and biofouling of the tower itself. Scaling, corrosion, and biofouling affect cooling tower performance and are the major maintenance items that are commonly handled by chemical treatment. Some of these chemicals contain priority pollutants.

3. Available technologies and techniques

(a) For control of TRC

The technologies and techniques for TRC control are essentially the same as discussed for once-through cooling (Part IV (A)(3) above).

(b) For control of 129 toxic pollutants discharged from chemicals added for cooling tower maintenance

Many power plants can avoid or minimize discharges of the 129 toxic pollutants from the cooling tower blowdown stream by using chemicals that do not contain the 129 toxic pollutants. Many plants are already using some of these readily available chemicals.

(c) For control of all pollutants from recirculating cooling water systems

Some plants (principally in the southwest) do not discharge cooling tower blowdown but use evaporation ponds to eliminate all discharges. In areas where net evaporation is less than 20 inches/year, this is not a practical technology. Vapor compression distillation (VCD) is sometimes used to reduce the volume of wastewater to be evaporated and to provide recovery of water for inplant use. VCD is a forced evaporation system which evaporates over 90 percent of the water. The vapor is condensed and reused by the plant as make-up water, and the remaining 10 percent is a concentrated brine that is disposed of in evaporation ponds or spray dryers.

(d) For control of heavy metals

An available option for removal of chromium and zinc is precipitation. This treatment method involves the addition of chemicals to precipitate the dissolved metals and sedimentation or filtration to remove suspended solids. This technology is required under existing BAT. This treatment method is effective in lowering amounts of dissolved metals.

4. Proposed Regulation

a. BAT

The Agency is proposing to limit TRC discharges to a maximum concentration of 0.14 mg/l at any time. The Agency is also proposing to prohibit the discharge of all chemicals used for tower and condenser maintenance that contain any of the 129 toxic priority pollutants. Plants with cooling towers are not required to demonstrate the need to chlorinate or to undergo a minimization program.

For Control of TRC: One technology that is available to achieve the .14 mg/l TRC limit is dechlorination. In some cases, plants may be able to meet this limitation without dechlorination by using other good management practices, i.e., discontinuation of discharge for two to three hours until the TRC dissipates inside the system.

The Agency is not requiring a chlorine minimization program because such a program would be unduly complex for this stream (as compared to once-through cooling) since chlorine may be required for cooling tower maintenance as well as biofouling control in the condenser tubes. Moreover, minimization is not as important in this waste stream because the daily flow is commonly less than 1/100th of the once-through cooling water flow.

The Agency has rejected a no discharge limitation because it would either require the use of alternative biocides for biofouling control or would require vapor compression distillation. Some of these alternative biocides may be as toxic as chlorine. The Agency does not believe vapor compression distillation is a viable technology for the treatment of this waste stream since disposal of the brine wastes in an environmentally acceptable manner may not be technically feasible in some cases and, may be too expensive in some geographical locations.

Thus, because dechlorination is clearly technologically and economically achievable, the Agency has determined that the 0.14 mg/l limit, which can be met by dechlorination, is BAT for the control of TRC. Meeting this limit will result in reasonable further progress toward the Act's no discharge goal.

For control of the 129 toxic pollutants: Many chemicals are available for cooling tower maintenance that do not contain any of the 129 toxic pollutants, and these chemicals can effectively and economically protect cooling towers and system equipment from scaling, corrosion, and biofouling problems. High levels of chromium and zinc are present in cooling tower blowdown only if they were added for tower maintenance. Although precipitation reduces the discharge of these chemicals, it will not be able to eliminate it as in the case of using replacement material. Therefore, BAT for this stream prohibits the use of chemicals containing the 129 pollutants (no discharge of chemicals added for cooling tower maintenance).

For Control of Phosphorus: Phosphorus is used in cooling towers primarily for scaling control. The existing BAT requires treatment of phosphorus to 5 mg/l. The Agency has determined that this requirement is not necessary because 1) the limited use of phosphorus in cooling towers and 2) the environmental impact is quite site specific. The Agency has determined that the environmental effect of this non-toxic/non-conventional pollutant is adequately addressed by water quality standards. The proposed BAT is, therefore, relaxed in this respect, and the current limitation for phosphorus will not apply.

b. NSPS

The proposed NSPS controls for cooling tower blowdown are identical to the proposed BAT controls. The same factors and considerations discussed in the BAT section immediately above apply here.

c. PSES and PSNS

For PSES and PSNS, EPA is proposing no limitations on TRC because most of the TRC dissipates before reaching the POTW and the remaining low levels do not warrant control. For the 129 priority pollutants and phosphorus, EPA is proposing PSES equal to BAT because the Act's legislative history indicates that pretreatment standards should be equivalent to BAT. Moreover, these pollutants (primarily chromium, zinc, and pentachlorophenol) are not compatible with POTW treatment and may interfere with POTW operation or limit their sludge disposal options. For PSES and PSNS, the Agency is proposing no limitations on phosphorus as in the case for BAT.

C. Ash Transport Water

1. Fly Ash

a. Pollutants Present

Table IV-1 lists those pollutants that were detected at least once in the EPA data base in greater concentrations in the effluents than in the influents. The following toxic pollutants are believed to be a result of transporting fly ash: arsenic, antimony, beryllium, selenium, nickel, lead, chromium, copper, zinc, cadmium, mercury, and thallium.

These materials enter the water primarily via dissolution of reactive compounds on the surface of the fly ash particles. Only plants handling fly ash with partially recirculating or wet once-through systems contribute to this problem. Gas-fired and nuclear plants do not generate ash. Further, out of approximately 850 steam electric plants, only 43 oil-fired plants and 183 coal-fired plants currently discharge fly ash sluice water (many of the oil-fired facilities do not collect fly ash and would not be affected by regulations for fly ash transport water).

b. Need to control toxics from this stream

The sampling data demonstrates that toxic pollutants are present in the fly ash transport water discharge stream; however, most of these pollutants are also present in the plants' make-up or intake water source. Data on concentrations of pollutants in the intake water and fly ash transport water discharges are limited to seven of approximately 25 plants (nationally) with separate fly ash ponds.

These data do not demonstrate a consistent pattern. That is, at certain plants the observed concentrations (or average concentrations) of some toxics are higher in the intake water than in the ash pond discharge while for other toxics the reverse is true. In other cases, effluent concentrations are higher than intake concentrations but the observed values are close to or at the detectable limit for the pollutant. The Agency's conclusion is that the present data base is not sufficient to support any reasonable estimation of net discharges of toxic pollutants for the industry from this waste source. This conclusion is based on the small numbers of observations and the large variation in the data.

3. Available technologies and techniques

(a) Dry fly ash transport

Currently 48 percent of the 352 coal-fired plants and 14 percent of the 429 oil-fired plants in the country use dry fly ash transport and disposal systems. Such systems of transport carry fly ash collected in precipitators to short-term storage vessels (silos) by vacuum or pressurized air. No water is used in the transport. The ash in the silos is trucked to landfill disposal sites.

A number of these facilities retrofitted their systems--that is, they replaced wet sluicing to ponds with the dry transport systems. This method of handling fly ash eliminates the discharge of all ash sluice water and thus eliminates priority pollutant discharge.

The motivation for retrofitting dry fly ash systems for these facilities may be the result of a water shortage in the area, state or local requirements, or a plant's desire to market the fly ash.

b. Partial recirculation of fly ash sluice water

Currently 52 percent of coal fired plants and 10 percent of oil fired plants wet sluice their fly ash to a disposal pond. This method carries ash from the fly ash hoppers to a settling pond or basin using water as the transport medium. Most plants operate in a once-through mode since they do not pump any of the ash water back to be reused. Of the plants wet sluicing fly ash, 9 percent of coal-fired plants partially recirculate the sluice water. The sluiced ash is commonly pumped to settling ponds and then flows to a clear pond where water is recirculated to the main sluice pumps. In partially recirculating systems, a portion of the clear pond overflow is discharged. Theoretically, partial recirculation reduces the flow of ash transport discharge and therefore the mass rate of discharge for priority pollutants; however, data to quantify the degree of toxic reduction are not available at the present time.

Essentially no major equipment need be removed in order to retrofit a partially recirculating system from a wet once-through system, other than the rerouting of old pipe. The addition of recirculation pumps to move the pond water, and a recirculation pond are required. The technology is in use today at some facilities and is available to all plants. The degree of water recycle/reuse practiced by existing facilities with recirculating systems varies. The Agency has not identified any plants with complete recirculation (no blowdown or point source discharge).

c. Chemical precipitation

Another available technology option is chemical precipitation of the final discharge from the partially recycled ash sluice water.

Chemical precipitation, in particular lime precipitation, has been demonstrated over many years as an effective method of removing heavy metals from aqueous solutions. The Agency has data to quantify arsenic removal to 50 ppb although the removal of other inorganic priority pollutants was also studied. The Agency has demonstrated the effectiveness of lime precipitation for reducing levels of metals in fly ash pond effluents in bench scale tests.

The Agency's data base indicates that approximately 10 percent of the plants discharging fly ash sluice water will have high levels of dissolved arsenic (exceeding .05 mg/l).

4. Proposed Regulation

a. BAT

The Agency is not proposing any additional controls for fly ash transport water beyond those established by BPT at this time. This decision is the result of careful consideration of factors including costs, treatment technology availability, quantity of pollutants removed, and other factors. The ash ponds generally used to achieve BPT limits already produce substantial reductions in the amounts of toxic pollutants discharged from fly ash transport water.

EPA seriously considered proposing a no-discharge limitation for all plants larger than 200 MW based upon dry fly ash transport. While EPA found this option to be technologically feasible for these plants, EPA has concluded that the extremely high costs to the industry ($3.19 billion in capital costs for 1980-1985) could not be justified in view of the inconclusive nature of the available data regarding the degree of toxic pollutant reduction to be achieved beyond BPT. EPA does not feel that it would be responsible to impose such costly additional requirements in the face of such uncertainity. Currently, 169 out of the 352 existing coal-fired plants already use dry methods of transport. EPA's decision is not based upon consideration of water quality impacts. The decision is based soley on the inconclusive nature of the data regarding the degree of effluent reduction that would be achieved.

Another option to eliminate discharge is through complete recirculation of ash transport water. However, the information available to the Agency at this time is not sufficient to determine if this system is technically achievable.

The Agency rejected partial recirculation (with blowdown) because data are not available at this time to support a specific numerical effluent limitation for any toxic pollutant; nor can the Agency conclude at this time that any non-toxic pollutant parameter (such as TSS) could serve as an "indicator" for toxic control from partial recirculation. In addition, more stringent limitations for conventional pollutions based on partial recirculation are not imposed because the cost will not pass the cost reasonableness test for Best Conventional Technology.

Precipitation has been explored as a technology option for inorganic priority pollutant removal from ash pond overflows. Precipitation is rejected because the mean concentrations of most of the inorganic pollutants from the untreated ash ponds overflow are less than the treated levels through precipitation from other industrial plants, and thus no technology transfer can be made. The Agency conducted a pilot study and determined that precipitation can remove inorganic pollutants from ash pond overflows; but the data are not sufficient to specify the removal level achievable at a full scale plant.

Precipitation is an option for treating arsenic at certain plants with high levels of arsenic. Existing data are available to specify a removal level for arsenic of 0.05 mg/l. This level is estimated to be exceeded by 10 percent of the coal-fired facilities. Although the precipitation technology option was not selected for proposal, it, together with the dry fly ash transport requirements will be seriously considered as an alternative BAT option in the future.

EPA has decided not to propose further control of fly ash transport water beyond BPT for existing sources at this time because the available data does not support the need for further control EPA is considering further sampling and industry profile studies that might allow the Agency to reasses its position. The Agency is publishing all available data and requesting public comment on how a program for further sampling and analyses might be conducted.

b. NSPS and PSNS

The proposed NSPS and PSNS prohibits all discharges of fly ash water. In light of the large number of plants already uisng dry fly ash systems, the technology is clearly demonstrated and available. Unlike BAT, the costs for a dry fly ash handling system are not appreciably different than costs for wet sluicing fly ash in a new plant. All new sources regardless of size are prohibited from discharging fly ash water. The Agency does not anticipate any of the new sources to discharge their fly ash transport water to POTWs.

c. PSES

For PSES, EPA is proposing no additional control beyond existing PSES. This is equivalent to no control.

D. Bottom Ash Transport Water

1. Pollutants detected in sampling program

Similar pollutants were detected in bottom ash transport water and fly ash transport water but the concentrations detected in bottom ash sluice water discharges were typically lower. Moreover, in comparison to the fly ash sampling data, the data on bottom ash water discharge displays a more consistent pattern of lower concentrations in the effluent than in the intake water. This is because the surface area of ash/unit weight available for leaching is greater for fly ash than bottom ash. Further, certain pollutants with low volatility temperature would be present in the bottom ash at very low concentrations (i.e., arsenic, mercury, etc.).

At most plants sampled, the concentrations of priority inorganic pollutants detected in the bottom ash pond were less than the concentrations detected in the raw or intake water source. The bottom ash data are still somewhat inconclusive due to small sample size and large variability. The pollutants detected in bottom ash transport water are summarized in Table VI-1 of Section VI.

2. Need to control toxics from this stream

The following priority inorganic pollutants were detected at least once in bottom ash effluent in the EPA sampling data base: antimony, nickel, arsenic, lead, beryllium, chromium, copper, cadmium, mercury, selenium, and zinc. In most cases, however, the observed effluent concentrations of these pollutants are smaller thand the intake water concentrations. Thus, the need to control toxic pollutants from this waste stream beyond BPT is warranted on the basis of the sampling data now available to the Agency.

3. Available technologies and techniques

(a) dry transport --

Approximately 70 plants currently transport their bottom ash using a dry system and report no discharge to the navigable waters. Dry transport of bottom ash entails the mechanical removal of the bottom ash from the bottom ash bin and mechanical transport (conveyor type) to a temporary storage vessel. The ash from the temporary storage vessel is transported by truck to the permanent disposal site. No water is required in this transport system. Dry handling of bottom ash is typical of plants with stoker-fired boilers. These plants usually have small capacities, with relatively small amounts of bottom ash generated.

(b) partial to complete recirculation --

Many plants recirculate their bottom ash transport water with a blowdown stream to control the buildup of dissolved solids. A completely recirculating system returns all of the ash sluice water to the ash collecting hoppers for repeated use in sluicing. A recirculating system can be operated at partial recirculation, usually 12.5 or 25 times recycle, or operated with a complete recycle of bottom ash sluice water. The Agency has not identified any plants with complete recirculation except those in arid areas using evaporation ponds to eliminate final discharge.

(c) precipitation --

This is the same treatment method as discussed in part 3(c) of the fly ash section.

4. Proposed Regulation

(a) BAT

No further control beyond BPT is proposed. The Agency has considered the above options and determined that in view of the waste characteristics and costs of control options, adequate control methods are imposed under BPT for this waste stream.

Dry transport of bottom ash for all plants is rejected because this technology is known to be adequate for handling only small amounts of bottom ash. The Agency does not believe that this technology is economically feasible and technically available on a national basis.

The Agency seriously considered the options of partial to complete recirculation of bottom ash sluice water. Although complete recirculation is concluded to be a technically feasible option, although the Agency is not proposing it. The high costs, and the fact that the data to quantify the effluent reduction beyond BPT are inadequate, are the two major reasons for not selecting this option. The Agency may gather additional information on this waste source (through the sampling program discussed above) and the Agency's positon may be reassessed upon review of the new information.

The Agency is proposing the withdrawal of the current BAT requirement of 12.5 recycle of bottom ash sluice water based on the removal of conventional pollutants because the "reasonableness" of this option using the cost tests for conventional pollutants in 40 CFR Part 405 (August 23, 1978) was assessed and for all plant sizes, the 12.5 recycle option did not pass the BCT test.

Precipitation is rejected because the effectiveness of this technology in bottom ash wastewater is uncertain. The mean concentrations of the inorganic priority pollutants are lower than the treated levels from other industries using this technology, and thus a technology transfer cannot be established. Bench scale studies applying this technology to ash pond effluents indicate effective removal of certain trace metals, but more studies are necessary to confirm these results.

(b) NSPS

For the same reasons that EPA is not proposing any requirements beyond BPT for existing sources, EPA is proposing to withdraw the current NSPS requirement of 20 times recycle and substitute the basic BPT requirement in its place. Unlike dry fly ash handling systems for new sources (which are no more costly than other fly as handling systems) a recycle system for bottom ash is substantially more expensive than other bottom ash handling systems.

(c) PSES and PSNS

The proposed PSES and PSNS do not restrict the discharge of any pollutants from this wastewater source. The costs of controlling priority inorganic pollutants and the low levels of pollutants detected do not warrant the imposition of effluent standards for this waste stream at this time.

E. Metal Cleaning Wastes

This document supercedes all previous memoranda on effluent limitations guidelines regarding the definition of metal cleaning wastes. Metal cleaning wastes include boiler tube cleaning waste, air preheater wash water and fireside wash water, with or without the use of chemicals during the cleaning process.

The limitations for iron and copper of 1 mg/l will not be changed. For those cases where chelating or complexing agents are used in the cleaning process, the treatment technology scheme may need to be altered. Lime treatment of these chelated wastes, together with air preheater and fireside wash water (at the proper ratio), will result in the achievement of the 1.0 mg/l limitation. An alternate precipitation scheme using sulfide will also achieve the 1.0 mg/l limit.

F. Low-Volume Wastes

The best practicable technology currently available is found to be adequate for control and is being defined as best available technology economically achievable. Boiler blowdown, which is currently considered as a separate waste category, is required to be treated for iron and copper. In reexamination of the waste characteristics information, boiler blowdown is now redefined as low-volume waste and, therefore, is no longer subject to the iron and copper limitations.

Application of Effluent Limitations Guidelines and Standards

A discussion of the application of the effluent limitations guidelines was presented in the 1974 Development Document (1). Certain aspects relating to the implementation of the original guidelines and recommended revisions are discussed below. In-plant dilution is permitted to achieve pH limitations. Consolidation of waste streams to a centralized treatment system is permitted and encouraged. The quantity of pollutant permitted to be discharged, however, is not always equal to the total flow times the effluent limitations guidelines. It would equal the effluent limitations guidelines times total flow only if all the raw waste streams contributing to the central treatment system have waste characteristics which exceed the guidelines. For cases where the dilution ratio would be so great that the analytical method is not accurate enough to distinguish the difference (such as low volume wastes containing oil and grease exceeding 15 mg/l are discharged to ash ponds), monitoring at the point prior to mixing (or dilution) would be required. The same analogy can be used for any stream and any pollutant.

SECTION X

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Gulf Power Company
Long Island Lighting
Natural Rural Electric
Nevada Power Company
Northern States Power Company
Pacific Power and Light
Pennsylvania Power and Light Company
Public Service Electric & Gas
Southern California Edison
Tampa Electric Company
Tennessee Valley Authority
Utah Power and Light
Wisconsin Electric Power Company

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SECTION IX

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SECTION XII

GLOSSARY

This section is an alphabetical listing of technical terms (with definitions) used in this document which may not be familiar to the reader.

Absolute Pressure

The total force per unit area measured above absolute vacuum as a reference. Standard atmospheric pressure is 101,326 N/m^2 (14.696 psi) above absolute vacuum (zero pressure absolute).

Absolute Temperature

The temperature measured from a zero at which all molecular activity ceases. The volume of an ideal gas is directly proportional to its absolute temperature. It is measured in ±K (±R) corresponding to ±C + 273 (±F + 459).

Acid

A substance which dissolves in water with the formation of hydrogen ion. A substance containing hydrogen which may be displaced by metals to form salts.

Acid-Washed Activated Carbon

Carbon which has been contacted with an acid solution with the purpose of dissolving ash in the activated carbon.

Acidity

The quantitative capacity of aqueous solutions to react with hydroxyl ions (OH^-). The condition of a water solution having a pH of less than 7.

Acre-Foot

(1) A term used in measuring the volume of water that is equal to the quantity of water required to cover 1 acre 1 foot deep, or 43,560 ft^3.

(2) A term used in sewage treatment in measuring the volume of material in a trickling filter. One acre-foot contains 43,560 ft^3 of water.

Activated Carbon

Carbon which is treated by high-temperature heating with steam or carbon dioxide producing an internal porous particle structure.

Absorption

The adhesion of an extremely thin layer of molecules (of gas, liquid) to the surfaces of solids (granular activated carbons for instance) or liquids with which they are in contact.

Adsorption Isotherms (Activated Carbon)

A measurement of adsorption determined at a constant temperature by varying the amount of carbon used or the concentration impurity in contact with the carbon.

Advanced Waste Treatment

Any treatment method or process employed following biological treatment (1) to increase the removal of pollution load, (2) to remove substances which may be deleterious to receiving waters or the environment, (3) to produce a high-quality effluent suitable for reuse in any specific manner or for discharge under critical conditions. The term tertiary treatment is commonly used to denote advanced waste treatment methods.

Aerated Pond

A natural or artificial wastewater treatment pond in which mechanical or diffused air aeration is used to supplement the oxygen supply.

Aeration

The bringing about of intimate contact between air and liquid by one of the following methods; spraying the liquid in the air, bubbling air through the liquid (diffused aeration), agitation of the liquid to promote surface absorption of air (mechanical aeration).

Agglomeration

The coalesence of dispersed suspended matter into larger flocs or particles which settle more rapidly.

Algicide

Chemicals used to kill or otherwise control phytoplankton (algae) in water.

Alkaline

The condition of a water solution having a pH concentration greater than 7.0 and having the properties of a base.

Alkalinity

The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is expressed in miligrams per liter or equivalent calcium carbonate.

Anion

The charged particle in a solution of an electrolyte which carries a negative charge.

Anion Exchange Process

The reversible exchange of negative ions between functional groups of the ion exchange medium and the solution in which the solid is immersed. Used as a wastewater treatment process for removal of anions, e.g., carbonate.

Anionic Surfactant

An ionic type of surface-active substance that has been widely used in cleaning products. The hydrophilic group of these surfactants carries a negative charge in washing solution.

Anthracite

A hard natural coal of high luster which contains little volatile matter.

Apparent Density (Activated Carbon)

The weight per unit volume of activated carbon.

Approach Temperature

The difference between the exit temperature of water from a cooling tower and the wet bulb temperature of the air.

Aquifer

A subsurface geological structure that contains water.

Ash

The solid residue following combustion as a fuel.

Ash Sluice

The transport of solid residue ash by water flow in a conduit.

Backwashing

The process of cleaning a rapid sand or mechanical filter by reversing the flow of water.

Baffles

Deflector vanes, guides, grids, gratings, or similar devices constructed or placed in flowing water or sewage to (1) check or effect a more uniform distribution of velocities; (2) absorb energy; (3) divert, guide, or agitate the liquids, and (4) check eddy currents.

Bag Filter

A fabric type filter in which dust laden gas is made to pass through woven fabric to remove the particulate matter.

Banks, Sludge

Accumulations on the bed of a waterway of deposits of solids of sewage or industrial waste origin.

Base

A compound which dissolves in water to yield hydorxyl ions (OH-).

Base-Load Unit

An electric generating facility operating continuously at a constant output with little hourly or daily fluctuation.

Bed Depth (Activated Carbon)

The amount of carbon expressed in length units which is parallel to the flow of the stream and through which the stream must pass.

Bioassay

An assay method using a change in biological activity as a qualitative or quantitative means of analyzing a meateerial response to industrial wastes and other wastewaters by using viable organisms or live fish as test organisms.

Biochemical Oxygen Demand (BOD)

(1) The quantity of oxygen used in the biochemicaoxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

(2) Standard test used in accessing wastewater strength.

Biocides

Chemical agents with the capacity to kill biological life forms. Bactericides, insecticides, pesticides, etc., are examples.

Biodegradable

The part of organic matter which can be oxidized by bioprocesses, biodegradable detergents, food wastes, animal manure.

Biological Wastewater Treatment

Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filters, contact beds, trickling filters, and activated sludge process are examples.

Bituminous

A coal of intermediate hardness containing between 50 and 92 percent carbon.

Blowdown

A portion of water in a closed system which is removed or discharged in order to prevent a buildup of dissolved solids.

Boiler

A device in which a liquid is converted into its vapor state by the action of heat. In the steam electric generating industry, the equipment which converts water into steam.

Boiler Feedwater

The water supplied to a boiler to be converted into steam.

Boiler Fireside

The surface at which the boiler heat exchange elements are exposed to the hot combustion products.

Boiler Scale

A deposit of salts on the waterside of a boiler as a result of the evaporation of water.

Boiler Tubes

Tubes contained in a boiler through which water passes during its conversion into steam.

Bottom Ash

The solid residue left from the combustion of a fuel which falls to the bottom of the combustion chamber.

Brackish Water

Water having a dissolved solids content between that of fresh water and that of sea water, generally from 1,000 to 10,000 mg per liter.

Brine

Water saturated with a salt.

Buffer

Any of certain combinations of chemicals used to stabilize the pH values or alkalinities of solutions.

Cake, Sludge

The material resulting from air drying or dewatering sludge (usually forkable or spadable).

Calibration

The determination, checking or rectifying of the graduation of any instrument given quantitative measurements.

Capacity Factor

The ratio of energy actually produced to that which would have been produced in the same period had the unit been operated continuously at rated capacity.

Carbonate Hardness

Hardness of water caused by the presence of carbonates and bicarbonates of calcium and magnesium.

Carbon Column A

A column filled with granular activated carbon whose primary function is the preferential adsorption of a particular type or types of molecules.

Catalyst

A substance which accelerates or retards a chemical reaction without undergoing any permanent changes.

Cation

The charged particles in solution of an electrolyte which are positively charged.

Cation Exchange Process

The reversible exchange of positive ions between functional groups of the ion exchange medium and the solution in which the solid is immersed. Used as a wastewater treatment process for removal of cations, e.g., calcium.

Cationic Surfactant

A surfactant in which the hydrophilic groups are positively charged; usually a quaternary ammonium salt such as cetyl trimethyl ammonium bromide (CeTAB), $C_{16}H_{33}N + (CH_3)_3\ Br$. Cationic surfactants, as a class, are poor cleaners but exhibit remarkable disinfectant properties.

Chelating Agents

A chelating agent can attache itself to central metallic atom so as to form a heterocyclic ring. Used to make ion exchange more selective for specific metal ions such as nickel, copper, and cobalt.

Chemical Analysis

The use of a standard chemical analytical procedure to determine the concentration of a specific pollutant in a wastewater sample.

Chemical Coagulation

The destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical.

Chemical Oxygen Demand (COD)

A specific test to measure the amount of oxygen required for the complete oxidation of all organic and inorganic matter in a water sample which is susceptible to oxidation by a strong chemical oxidant.

Chemical Precipitation

(1) Precipitation induced by addition of chemicals.

(2) The process of softening water by the addition of lime and soda ash as the precipitants.

Chemisorption

Adsorption where the forces holding the adsorbate to the adsorbent are chemical (valance) instead of physical (van der Waals).

Chlorination

The application of chlorine to water or wastewater, generally for the purpose of disinfection but frequently for accomplishing other biological or chemical results.

Chlorination Break Point

The application of chlorine to water, sewage, or industrial waste containing free ammonia to the point where free residual chlorine is available.

Chlorination, Free Residual

The application of chlorine to water, sewage, or industrial wastes to produce directly or through the destruction of ammonia, or of certain organic nitrogenous compounds, a free available chlorine residual.

Chlorine, Available

A term used in rating chlorinated lime and hypochlorites as to their total oxidizing power. Also, a term formerly applied to residual chlorine; now obsolete.

Chlorine, Combined Available Residual

That portion of the total residual chlorine remaining in water, sewage, or industrial wastes at the end of specified contact period which will react chemically and biologically as chloramines or organic chloramines.

Chlorine Demand

The quantity of chlorine absorbed by wastewater (or water) in a given length of time.

Chlorine, Total Residual

Free residual plus combined residual.

Clorite, High-Test Hypo

A combination of lime and chlorine consisting largely of calcium hypochloride.

Chlorite, Sodium Hypo

A water solution of sodium hydroxide and chlorine in which sodium hypochlorite is the essential ingredient.

Circulating Water Pumps

Pumps which deliver cooling water to the condensers of a powerplant.

Circulating Water System

A system which conveys cooling water from its source to the main condensers and then to the point of discharge. Synonymous with cooling water system.

Clarification

A process for the removal of suspended matter from a water solution.

Clarifier

A basin in which water flows at a low velocity to allow settling of suspended matter.

Colloids

A finely divided dispersion of one material called the "dispersed phase" (solid); in another material which is called the "dispersion medium" (liquid). Normally negatively charged.

Closed Circulating Water System

A system which passes water through the condensers then through an artificial cooling device and keeps recycling it.

Coal Pile Drainage

Runoff from the coal pile as a result of rainfall.

Condensate Polisher

An ion exchanger used to adsorb minute quantities of cations and anions present in condensate as a result of corrosion and erosion of metallic surfaces.

Condenser

A device for converting a vapor into its liquid phase.

Construction

Any placement, assembly, or installation of facilities or equipment (including contractual obligations to purchase such facilities or equipment) at the premises where the equipment will be used, including preparation work at the premises.

Convection The heat transfer mechanism arising from the motion of a fluid.

Composite Wastewater Sample

A combination of individual samples of water or wastewater taken at selected intervals, generally hourly for some specified period, to minimize the effect of the variability of the individual samle. Individual samples may have equal volume or may be roughly proportioned to the flow at time of sampling.

Concentration, Hydrogen Ion

The weight of hydrogen ions in grams per liter of solution. Commonly expressed as the pH value that represents the logarithms of the reciprocoal of the hydrogen ion concentration.

Cooling Canal

A canal in which warm water enters at one end, is cooled by contact with air, and is discharged at the other end.

Cooling Tower

A configured heat exchange device which transfers rejected heat from circulating water to the atmosphere.

Cooling Tower Basin

A basin located at the bottom of a cooling tower for collecting the falling water.

Cooling Water System

See Circulating Water System.

Corrosion Inhibitor

A chemical agent which slows down or prohibits a corrosion reaction.

Counterflow

A process in which two mediae flow through a system in opposite directions.

Critical Point

The temperature and pressure conditions at which the saturated liquid and saturated vapor states of a fluid are identical. For water-steam, these conditions are 3208.2 psia and 705.47 ±F.

Cycling Plant

A generating facility which operates between peak load and base load conditions.

Cyclone Furnace

A water-cooled horizontal cylinder in which fuel is fired, heat is released at extremely high rates, and combustion is completed. The hot gases are then ejected into the main furnace. The fuel and combustion air enter tangentially imparting a whirling motion to the burning fuel, hence the name Cyclone Furance. Molten slag forms on the cylinder walls and flows off for removal.

Data

Records of observations and measurements of physical facts, occurrences, and conditions reduced to written, graphical, or tabular form.

Data Correlation

The process of the conversion of reduced data into a functional relationship and the development of the significance of both the data and the relationship for the purpose of process evaluation.

Data Reduction

The process for the conversion of raw field data into a systematic flow which assists in recognizing errors, omissions, and the overall data quality.

Data Significance

The result of the statistical analysis of a data group or bank wherein the value or significance of the data receives a thorough appraisal.

Deaeration

A process by which dissolved air and oxygen are stripped from water either by physical or chemical methods.

Deaerator

A device for the removal of oxygen, carbon dioxide, and other gases from water.

Dechlorination Process

A process by which excess chlorine is removed from water to a desired level, e.g., 0.1 mg/l maximum limit. Usually accomplished by passage through carbon beds or by aeration at a suitable pH.

Degasification

The removal of a gas from a liquid.

Deionizer

A process for treating water by removal of cations and anions.

Demineralizer

See Deionizer.

Demister

A device for trapping liquid entrainment from gas or vapor streams.

Detention Time

The time allowed for solids to collect in a settling tank. Theoretically, detention time is equal to the volume of the tank divided by the flow rate. The actual detention time is determined by the purpose of the tank. Also, the design resident time in a tank or reaction vessel which allows a chemical reaction to go to completion, such as the reduction of chromium +6 or the destruction of cyanide.

Dewater

To remove a portion of the water from a sludge or a slurry.

Dew Point

The temperature of a gas-vapor mixture at which the vapor condenses when it is cooled at constant humidity.

Diatomaceous Earth

A filter medium used for filtration of effluents from secondary and tertiary treatments, particularly when a very high grade of water for reuse in certain industrial purposes is required. Also used as an adsorbent for oils and oily emulsions in some wastewater treatment designs.

Diesel

An internal combustion engine in which the temperature at the end of the compression is such that combustion is initiated without external ignition.

Discharge

To release or vent.

Discharge Pipe

A section of pipe or conduit from the condenser discharge to the point of discharge into receiving waters or cooling device.

Dissolved Solids

Theoretically, the anhydrous residues of the dissolved constituents in water. Actually, the term is defined by the method used in determination. In water and wastewater treatment, the Standard Methods tests are used.

Diurnal Flow Curve

A curve which depicts flow distribution over the 24-hour day.

Drift

Entrained water carried from a cooling device by the exhaust air.

Dry Bottom Furnace

Refers to a furnace in which the ash leaves the boiler bottom as a solid (as opposed to a molten slag).

Dry Tower

A cooling tower in which the fluid to be cooled flows within a closed system which transfers heat to the environment using finned or extented surfaces.

Dry Well

A dry compartment of a pump structure at or below pumping level where pumps are located.

Economizer

A heat exchanger which uses the heat of combustion gases to raise the boiler feedwater temperature before the feedwater enters the boiler.

Economizer Ash

Carryover ash from the boiler which due to its size and weight, settles in a hopper below the economizer.

Effluent

(1) A liquid which flows out of a containing space.

(2) Sewage, water or other liquid, partially or, as the case may be, flowing out of a reservoir basin, treatment plant, or part thereof.

ElectroStatic Precipitator

A device for removing particles from a stream of gas based on the principle that these particles carry electrostatic charges and can therefore be attracted to an electrode by imposing a potential across the stream of gas.

Evaporation

The process by which a liquid becomes a vapor.

Evaporator

A device which converts a liquid into a vapor by the addition of heat.

Feedwater Heater

Heat exchangers in which boiler feedwater is preheated by steam extracted from the turbine.

Filter Bed

A device for removing suspended solids from water, consisting of granular material placed in a layer(s) and capable of being cleaned hydraulically by reversing the direction of the flow.

Filter, High-Rate

A trickling filter operated at a high average daily dosing rate. All between 10 and 30 mgd/acre, sometimes including recirculation of effluent.

Filter, Intermittent

A natural or artificial bed of sand or other fine-grained material to the surface of which sewage is intermittently added in flooding doses and through which it passes, opportunity being given for filtration and the maintenance of aerobic conditions.

Filter, Low-Rate

A trickling filter designed to receive a small load of BOD per unit volume of filtering material and to have a low dosage rate per unit of surface area (usually 1 to 4 mgd/acre). Also called standard rate filter.

Filter, Rapid Sand

A filter for the purification of water where water which has been previously treated, usually by coagulation and sedimentation, is passed downward through a filtering medium consisting of a layer of sand or prepared anthracite coal or other suitable material, usually from 24 to 30 inches thick and resting on a supporting bed of gravel or a porous median such as carborundum. The filtrate is removed by an underdrain system. The filter is cleaned periodically by reversing the flow of the water upward through the filtering medium; sometimes supplemented by mechanical or air agitation during backwashing to remove mud and other impurities that are lodged in the sand.

Filter, Vacuum

A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth revolving with a partial submergence in liquid. A vacuum is maintained under the cloth for the larger part of a revolution to extract moisture and the cake is scraped off continuously.

Filtration

The process of passing a liquid through a filtering medium for the removal of suspended or colloidal matter.

Fireside Cleaning

Cleaning of the outside surface of boiler tubes and combustion chamber refractories to remove deposits formed during the combustions.

Floc

A very fine, fluffy mass formed by the aggregation of fine suspended particles.

Flocculator

An apparatus designed for the formation of floc in water or sewage.

Flocculation

In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gently stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

Flow Rate

Usually expressed as liters/minute (gallons/minute) or liters/day (million gallons/day). Design flow rate is that used to size the wastewater treatment process. Peak flow rate is 1.5 to 2.5 times design and relates to the hydraulic flow limit and is specified for each plant. Flow rates can be mixed as batch and continuous where these two treatment modes are used on the same plant.

Flow-Nozzle Meter

A water meter of the differential medium type in which the flow through the primary element or nozzle produces a pressure difference or differential head, which the secondary element or float tube then uses as an indication of the rate of flow.

Flue Gas

The gaseous products resulting from the combustion process after passage through the boiler.

Fly Ash

A portion of the noncombustible residue from a fuel which is carried out of the boiler by the flue gas.

Fossil Fuel

A natural solid, liquid, or gaseous fuel such as coal, petroleum, or natural gas.

Frequency Distribution

An arrangement or distribution of quantities pertaining to a single element in order of their magnitude.

Gauging Station

A location on a stream or conduit where measurements of discharge are customarily made. The location includes a stretch of channel through which the flow is uniform and a control downstream from this stretch. The station usually has a recording or other gauge for measuring the elevation of the water surface in the channel or conduit.

Grab Sample

A single sample of wastewater taken at neither a set time nor flow.

Generation

The conversion of chemical or mechanical energy into electrical energy.

Hardness

A characteristic of water, imparted by salts of calcium, magnesium, and iron, such as bicarbonates, carbonates, sulfates, chlorides, and nitrates, that causes curdling of soap, deposition of scale in boilers, damage in some industrial process, and sometimes objectionable taste. It may be determined by a standard laboratory procedure or computed from the amounts of calcium and magnesium as well as iron, aluminum, manganese, barium, strontium, and zinc, and is expressed as equivalent calcium carbonate.

Heat of Absorption

The heat given off when molecules are adsorbed.

High Rate

The fuel heat input (in Joules or Btu's) required to generate a kWh.

Heating Value

The heat available from the combustion of a given quantity of fuel as determined by a standard calorimetric process.

Humidity

Pounds of water vapor carried by 1 pound of dry air.

Ion

A charged atom, molecule or radical, the migration of which affects the transport of electricity through an electrolyte.

Ion Exchange

A chemical process involving reversible interchange of ions between a liquid and solid but no radical change in the structure of the solid.

Incineration

The combustion (by burning) of organic matter in wastewater sludge solids after water evaporation from the solids.

Lagoon

(1) A shallow body of water as a pond or lake which usually has a shallow, restricted inlet from the sea.

(2) A pond containing raw or partially treated wastewater in which aerobic or anerobic stabilization occurs.

Lignite

A carbonaceous fuel ranked between peat and coal.

Lime

Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite) which is composed almost wholly of calcium carbonate or a mixture of calcium and magnesium carbonates.

Makeup Water Pumps

Pumps which provide water to replace that lost by evaporation, seepage, and blowdown.

Manometer

An instrument for measuring pressure. It usually consists of a U-shaped tube containing a liquid, the surface of which moves proportionally with changes in pressure on the liquid in the other end. Also, a tube type of differential pressure gauge.

Mean Velocity

The average velocity of a stream flowing in a channel or conduit at a given cross section or in a given reach. It is equal to the discharge divided by the cross sectional area of the reach. Also called average velocity.

Mechanical Draft Tower

A cooling tower in which the air flow through the tower is maintained by fans. In forced draft towers, the air is forced through the tower by fans located at its base; whereas in induced draft towers, the air is pulled through the tower by fans mounted on top of the tower.

Mesh Size (Activated Carbon)

The particle size of granular activated carbon as determined by the U.S. Sieve series. Particle size distribution within a mesh series is given in the specification of the particular carbon.

Milligrams Per Liter (mg/l)

This is a weight per volume designation used in water and wastewater analysis.

Mine-Mouth Plant

A steam electric powerplant located within a short distance of a coal mine and to which the coal is transported from the mine by a conveyor system, slurry pipeline, or truck.

Mixed-Media Filtration

A filter which uses two or more filter materials of differing specific gravities selected so as to produce a filter uniformly graded from coarse to fine.

Mole

The molecular weight of a substance expressed in grams (or pounds).

Monitoring

(1) The procedure or operation of locating and measuring radioactive contamination by means of survey instruments that can detect and measure, as dose rate, ionizing radiations.

(2) The measurements, sometimes continuous, of water quality.

Name Plate

Name plate--design rating of a plant or specific piece of equipment.

Natural Draft Cooling Tower

A cooling tower through which air is circulated by a natural or chimney effect. A hyperbolic tower is a natural draft tower that is hyperbolic in shape.

Neutralization

Reaction of acid or alkaline solutions with the opposite reagent until the concentrations of hydrogen and hydorxyl ions are about equal.

New Source

Any source, the construction of which is begun after the publication of proposed Section 306 regulations, (March 4, 1974 for the Steam Electric Power Generating Point Source Category).

Nominal Capacity

See Name Plate.

Nuclear Energy

The energy derived from the fission of nuclei of heavy elements such as uranium or thorium or from the fusion of the nuclei of light elements such as deuterium or tritium.

Once-Through Circulating Water System

A circulating water system which draws water from a natural source, passes it through the main condensers, and returns it to a natural body of water.

Osmosis

The process of diffusion of a solvent through a semipermeable membrane from a solution of lower to one of higher concentration.

Osmotic Pressure

The equilibrium pressure differential across a semipermeable membrane which separates a solution of lower from one of higher concentration.

Overflow

(1) Excess water over the normal operating limits disposed of by letting it flow out through a device provided for that purpose. (2) The device itself that allows excess water to flow out.

Outfall

The point or location where sewage or drainage discharges from a sewer, drain, or conduit.

Oxidation

The addition of oxygen to a chemical compound, generally any reaction which involves the loss of electrons from an atom.

Package Sewage Treatment Plant

A sewage treatment facility contained in a small area and generally prefabricated in a complete package.

Packing (Cooling Towers)

A media providing large surface area for the purpose of enhancing mass and heat transfer, usually between a gas vapor and a liquid.

Peak-Load Plant

A generating facility operated only during periods at maximum demand.

pH Value

A scale for expressing the acidity or alkalinity of a solution. Mathematically, it is the logarithm of the reciprocal of the gram ionic hydrogen equivalents per liter. Neutral water has a pH of 7.0 and hydrogen ion concentration of 107 moles per liter.

Placed in Service

Refers to the data when a generating unit initially generated electrical power to service customers.

Plant Code Number

A four-digit number assigned to all powerplants in the industry inventory for the purpose of this study.

Plume (Gas)

A conspicuous trail of gas or vapor emitted from a cooling tower or chimney.

Pond, Sewage Oxidation

A pond, either natural or artificial, into which partly treated sewage is discharged and in which natural purification processes take place under the influence of sunlight and air.

Powerplant

Equipment that produces electrical energy generally by conversion from heat energy produced by chemical or nuclear reaction.

Precipitation

A phenomenon that occurs when a substance held in solution in a liquid phase passes out of solution into a solid phase.

Preheater (Air)

A unit used to heat the air needed for combustion of absorbing heat from the products of combustion.

Psychrometric

Refers to air-water vapor mixtures and their properties. A psychrometric chart graphically displays the relationship between these properties.

Pulverized Coal

Coal that has been ground to a powder, usually of a size where 80 percent passes through a #200 U.S.S. sieve.

Pyrites

Combinations of iron and sulfur found in coal as FeS_2.

Radwaste

Radioactive waste streams from nuclear powerplants.

Range

Difference between entrance and exit temperature of water in a cooling tower.

Rank of Coal

A classification of coal based upon the fixed carbon as a dry weight basis and the heat value.

Rankine Cycle

The thermodynamic cycle which is the basis of the steam electric generating process.

Recirculation System

Facilities which are specifically designed to divert the major portion of the cooling water discharge back for reuse.

Reduction

A chemical reaction which involves the addition of electrons to an ion to decrease its positive valence.

Regeneration

Displacement from ion exchange resins of the ions removed from the process solution.

Reheater

A heat exchange device for adding superheat to steam which has been partially expanded in the turbine.

Reinjection

To return a flow, or portion of flow, into a process.

Relative Humidity

Ratio of the partial pressure of the water vapor to the vapor pressure of water at air temperature.

Residual Chlorine

Chlorine remaining in water or wastewater at the end of specified contact period as combined or free chlorine.

Reverse Osmosis

The process of diffusion of a solute through a semipermeable membrane from a solution of lower to one of higher concentration, affected by raising the pressure of the less concentrated solution to above the osmotic pressure.

Salinity

(1) The relative concentration of salts, usually sodium chloride, in a given water. It is usually expressed in terms of the number of parts per million of chloride (Cl).

(2) A measure of the concentration of dissolved mineral substances in water.

Sampler

A device used with or without flow measurement to obtain any adequate portion of water or waste for analytical purposes. May be designed for taking a single sample (grab), composite sample, continuous sample, or periodic sample.

Sampling Stations

Locations where several flow samples are tapped for analysis.

Sanitary Wastewater

Wastewater discharged from sanitary conveniences of dwellings and industrial facilities.

Saturated Air

Air in which water vapor is in equilibrium with liquid water at air temperature.

Saturated Steam

Steam at the temperature and pressure at which the liquid and vapor phase can exist in equilibrium.

Scale

Generally insoluble deposits on equipment and heat transfer surfaces which are created when the solubility of a salt is exceeded. Common scaling agents are calcium carbonate and calcium sulfate.

Scrubber

A device for removing particles or objectionable gases from a stream of gas.

Secondary Treatment

The treatment of sanitary wastewater by biological means after primary treatment by sedimentation.

Sedimentation

The process of subsidence and deposition of suspended matter carried by a liquid.

Sequestering Agents

Chemical compounds which are added to water systems to prevent the formation of scale by holding the insoluble compounds in suspension.

Service Water Pumps

Pumps providing water for auxiliary plant heat exchangers and other uses.

Settleable Solids

(1) That matter in wastewater which will not stay in suspension during a preselected settling period, such as 1 hour but either settles to the bottom or floats to the top.

(2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in 1 hour.

Slag Tap Furnace

Furnace in which the temperature is high enough to maintain ash (slag) in a molten state until it leaves the furnace through a tap at the bottom. The slag falls into the sluicing water where it cools, disintegrates, and is carried away.

Slimicide

An agent used to destroy or control slimes.

Sludge

Accumulated solids separated from a liquid during processing.

Softener

Any device used to remove hardness from water. Hardness in water is due mainly to calcium and magnesium salts. Natural zeolites, ion exchange resins, and precipitation processes are used to remove the calcium and magnesium.

Spinning Reserve

The power generating reserve connected to the bus bar and ready to take load. Normally consists of units operating at less than full load. Gas turbines, even though not running, are considered spinning reserve due to their quick startup time.

Spray Module (Powered Spray Module)

A water cooling device consisting of a pump and spray nozzle or nozzles mounted on floats and moored in the body of water to be cooled. Heat is transferred principally by evaporation from the water drops as they fall through the air.

Stabilization Lagoon

A shallow pond for storage of wastewater before discharge. Such lagoons may serve only to detain and equalize wastewater composition before regulated discharge to a stream, but often they are used for biological oxidation.

Stabilization Pond

A type of oxidation pond in which biological oxidation of organic matter is affected by natural or artifically accelerated transfer of oxygen to the water from air.

Steam Drum

Vessel in which the saturated steam is separated from the steam-water mixture and into which the feedwater is introduced.

Supercritical

Refers to boilers designed to operate at or above the critical point of water 22,100 kN/square meters and 374.0±C (3206.2 psia and 705.4±F).

Superheated Steam

Steam which has been heated to a temperature above that corresponding to saturation at a specific pressure.

Suspended Solids

(1) Solids which either float on the surface of or are in suspension in water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

(2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

Thermal Efficiency

The efficiency of the thermodynamic cycle in producing work from heat. The ratio of usable energy to heat input expressed as a percent.

Thickening

Process of increasing the solids content of sludge.

Total Dynamic Head (TDH)

Total energy provided by a pump consisting of the difference in elevation between the suction and discharge levels, plus losses due to unrecovered velocity heads and friction.

Total Solids

The total amount of solids in a wastewater in both solution and suspension.

Turbine

A device used to convert the energy of steam or gas into rotational mechanical energy and used as prime mover to drive electric generators.

Treatment Efficiency

Usually refers to the percentage reduction of a specific or group of pollutants by a specific wastewater treatment step or treatment plant.

Turbidmeter

An instrument for measurement of turbidity in which a standard suspension usually is used for reference.

Turbidity

(1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and adsorption of light rays.

(2) A measure of fine suspended matter in liquids.

(3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

Turbulent Flow

(1) The flow of a liquid past an object such that the velocity at any fixed point in the fluid varies irregularly.

(2) A type of liquid flow in which there is an unsteady motion of the particles and the motion at a fixed point varies in no definite manner. Sometimes called eddy flow, sinuous flow.

Unit

In steam electric generation, the basic sysem for power generation consisting of a boiler and its associated turbine and generator with the required auxiliary equipment.

Utility

(Public utility)--A company either investor-owned or publicly owned which provides service to the public in general. The electric utilities generate and distribute electric power.

Volatile Combustion Matter

The relatively light components in a fuel which readily vaporize at a relatively low temperature and which when combined or reacted with oxygen, giving out light and heat.

Wet Bottom Furnace

See slag-tap furnace.

Wet Bulb Temperature

The steady-state, nonequilibrium temperature reached by a small mass of water immersed under adiabatic conditions in a continuous stream of air.

Wet Scrubber

A device for the collection of particulate matter from a gas stream or adsorption of certain gases from the stream.

APPENDIX A

TVA RAW RIVER INTAKE AND ASH POND DISCHARGE DATA

Quarterly Samples

1973-1976

Table A-1

TVA PLANT A RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/73		4/2/73		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	6.4	NA	8.8	NA	3.7	NA	7.5
Ammonia as N, mg/l	NA	0.10	NA	0.49	NA	0.02	NA	0.04
Arsenic, mg/l	NA	0.023	NA	0.010	NA	0.015	NA	0.005
Barium, mg/l	NA	0.3	NA	0.2	NA	0.2	NA	0.2
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	0.037	NA	0.036	NA	0.023	NA	0.052
Calcium, mg/l	NA	170	NA	170	NA	180	NA	160
Chloride, mg/l	NA	6	NA	6	NA	7	NA	14
Chromium, mg/l	NA	0.049	NA	0.033	NA	0.012	NA	0.016
Conductivity, 25°C, umhos/cm	NA	750	NA	780	NA	750	NA	840
Copper, mg/l	NA	0.36	NA	0.35	NA	0.25	NA	0.30
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	480	NA	490	NA	490	NA	460
Iron, mg/l	NA	1.1	NA	0.97	NA	0.47	NA	0.42
Lead, mg/l	NA	<0.010	NA	0.100	NA	<0.010	NA	0.034
Magnesium, mg/l	NA	13	NA	16	NA	9.5	NA	15
Manganese, mg/l	NA	0.50	NA	0.56	NA	0.45	NA	0.50
Mercury, mg/l	NA	0.0006	NA	0.0006	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	0.13	NA	0.12	NA	0.11	NA	0.13
Phosphorous, mg/l	NA	0.18	NA	<0.03	NA	0.04	NA	0.03
Selenium, mg/l	NA	0.004	NA	<0.001	NA	<0.001	NA	<0.001
Silica, mg/l	NA	15	NA	14	NA	12	NA	14
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	680	NA	700	NA	570	NA	700
Solids, Suspended, mg/l	NA	17	NA	6	NA	<1	NA	3
Sulfate, mg/l	NA	410	NA	380	NA	300	NA	440
Zinc, mg/l	NA	1.4	NA	1.3	NA	1.2	NA	1.7

NA = Not Available

Table A-1 (Continued)

TVA PLANT A RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/15/74		4/8/74		7/15/74		10/8/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	5.7	13	6.7	6.6	1.0	3.6	1.1	7.9
Ammonia as N, mg/l	0.14	1.4	0.04	1.0	0.04	0.26	0.02	0.15
Arsenic, mg/l	<0.005	0.005	<0.005	<0.005	<0.005	0.005	<0.005	0.010
Barium, mg/l	0.1	0.2	0.4	0.4	0.2	0.3	0.2	0.2
Beryllium, mg/l	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.041	<0.001	0.030	<0.001	0.038	<0.001	0.037
Calcium, mg/l	24	110	27	94	41	94	41	110
Chloride, mg/l	4	5	4	5	9	8	9	6
Chromium, mg/l	0.021	0.17	0.024	0.056	<0.005	0.12	0.008	0.082
Conductivity, 25°C, umhos/cm	140	710	210	740	320	640	310	680
Copper, mg/l	0.19	0.45	0.14	0.30	0.08	0.16	0.04	0.30
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	69	340	91	320	140	280	90	310
Iron, mg/l	5.4	6.6	6.7	1.0	1.3	0.33	1.1	0.60
Lead, mg/l	0.02	0.20	<0.010	0.021	0.026	<0.024	0.038	0.064
Magnesium, mg/l	4.1	17	5.7	20	8.0	12	6.8	9.4
Manganese, mg/l	0.17	0.63	0.25	0.59	0.10	0.29	0.08	0.31
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	0.10	0.05	0.08	<0.05	0.06	<0.05	0.11
Phosphorous, mg/l	0.12	0.02	0.13	0.02	0.04	0.02	0.03	0.02
Selenium, mg/l	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	5.2	11	6.9	12	1.7	-	6.3	10
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Solids, Dissolved, mg/l	120	620	120	560	200	470	170	500
Solids, Suspended, mg/l	100	6	190	5	14	2	45	6
Sulfate, mg/l	6	280	28	430	24	240	15	380
Zinc, mg/l	0.09	2.7	0.12	1.1	0.08	1.3	0.06	1.4

Table A-1 (Continued)

TVA PLANT A RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	2/3/75		4/7/75		7/14/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.05	6.2	*	10	1.2	12	2.1	9.6
Ammonia as N, mg/l	0.10	1.2	0.02	0.75	0.04	0.54	0.14	3.1
Arsenic, mg/l	no sample	<0.005	<0.005	<0.005		0.010	0.005	0.035
Barium, mg/l	<0.1	<0.1	*	<0.1	<0.1	0.2	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	*	<0.01	<0.01	0.01	<0.01	<0.01
Cadmium, mg/l	0.004	0.025	*	0.051	0.001	0.057	<0.001	0.025
Calcium, mg/l	29	88	*	110	48	120	35	110
Chloride, mg/l	6	5	4	4	5	9	10	9
Chromium, mg/l	<0.005	0.052	*	0.016	<0.005	0.230	<0.005	0.029
Conductivity, 25°C, umhos/cm	240	590	190	740	280	1000	260	880
Copper, mg/l	0.05	0.24	*	0.35	0.04	0.41	0.09	0.43
Cyanide, mg/l	<0.01	<0.01	–	–	–	–	–	–
Hardness, mg/l	91	270	*	370	150	350	120	340
Iron, mg/l	1.4	2.2	*	8.6	1.4	4.0	1.9	1.5
Lead, mg/l	0.021	0.052	*	0.083	<0.010	0.150	0.022	0.042
Magnesium, mg/l	4.5	13	*	12	6.6	13	7.1	17
Manganese, mg/l	0.12	0.44	*	0.50	0.10	0.57	0.12	0.51
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	0.07	*	0.11	0.05	0.13	<0.05	<0.05
Phosphorous, mg/l	<0.01	<0.01	0.05	0.04	0.14	0.04	0.06	0.05
Selenium, mg/l	no sample	<0.002	<0.002	0.002	<0.002	<0.002	<0.001	<0.002
Silica, mg/l	8.0	9.3	5.6	12	6.0	20	5.4	15
Silver, mg/l	<0.01	<0.01	*	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	140	470	150	500	170	700	176	640
Solids, Suspended, mg/l	57	4	21	8	18	9	33	3
Sulfate, mg/l	30	290	28	340	18	390	21	270
Zinc, mg/l	0.14	0.82	*	1.2	0.06	1.8	0.10	1.0

*Bottle Broken

Table A-1 (Continued)

TVA PLANT A RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/8/76		4/13/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.2	9.5	1.0	7.4
Ammonia as N, mg/l	0.07	0.89	0.03	0.55
Arsenic, mg/l	<0.005	0.005	<0.005	<0.005
Barium, mg/l	<0.1	<0.1	<0.1	0.5
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.049	<0.001	0.025
Calcium, mg/l	42	92	32	110
Chloride, mg/l	5	6	6	5
Chromium, mg/l	<0.005	0.080	<0.005	0.011
Conductivity, 25°C, umhos/cm	240	660	220	760
Copper, mg/l	0.02	0.32	0.03	0.32
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	130	280	100	320
Iron, mg/l	1.2	5.6	1.3	2.0
Lead, mg/l	<0.010	0.050	<0.010	0.020
Magnesium, mg/l	5.4	13	5.5	11
Manganese, mg/l	0.10	0.46	0.12	0.46
Mercury, mg/l	<0.0002	<0.0002	<0.0002	NES
Nickel, mg/l	<0.05	0.05	<0.05	<0.05
Phosphorous, mg/l	0.04	0.06	0.04	0.03
Selenium, mg/l	<0.002	-	<0.002	<0.002
Silica, mg/l	7.0	14	*	13
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	150	480	130	510
Solids, Suspended, mg/l	31	25	36	9
Sulfate, mg/l	16	320	16	190
Zinc, mg/l	0.02	0.74	0.06	0.85

*Bottle Empty

Table A-2

TVA PLANT A RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/2/73		4/2/73		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	2.6	NA	0.9	NA	8.0	NA	0.7
Ammonia as N, mg/l	NA	0.06	NA	0.06	NA	0.06	NA	0.22
Arsenic, mg/l	NA	0.002	NA	0.005	NA	0.015	NA	<0.005
Barium, mg/l	NA	<0.1	NA	<0.1	NA	0.1	NA	0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	33	NA	33	NA	44	NA	67
Chloride, mg/l	NA	6	NA	8	NA	8	NA	15
Chromium, mg/l	NA	<0.005	NA	<0.005	NA	<0.005	NA	<0.005
Conductivity, 25°C, umhos/cm	NA	250	NA	250	NA	290	NA	400
Copper, mg/l	NA	0.04	NA	<0.01	NA	0.08	NA	0.03
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	110	NA	110	NA	140	NA	170
Iron, mg/l	NA	3.8	NA	2.0	NA	7.5	NA	2.1
Lead, mg/l	NA	<0.010	NA	0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	5.7	NA	6.7	NA	6.7	NA	0.3
Manganese, mg/l	NA	0.12	NA	0.14	NA	0.25	NA	0.15
Mercury, mg/l	NA	0.0008	NA	0.0004	NA	<0.0026	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	0.12
Phosphorous, mg/l	NA	0.17	NA	<0.03	NA	0.36	NA	0.09
Selenium, mg/l	NA	0.002	NA	<0.004	NA	<0.001	NA	<0.001
Silica, mg/l	NA	7.3	NA	8.1	NA	6.1	NA	8.6
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	170	NA	180	NA	180	NA	260
Solids, Suspended, mg/l	NA	27	NA	13	NA	74	NA	6
Sulfate, mg/l	NA	41	NA	45	NA	50	NA	80
Zinc, mg/l	NA	0.08	NA	0.03	NA	0.07	NA	0.02

NA = Not Available

Table A-2 (Continued)

TVA PLANT A RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/15/74		4/8/74		7/15/74		10/8/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	5.7	6.0	6.7	7.9	1.0	0.5	1.1	1.3
Ammonia as N, mg/l	0.14	0.05	0.04	0.34	0.04	0.12	0.02	0.04
Arsenic, mg/l	<0.005	0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005
Barium, mg/l	0.1	0.1	0.4	0.3	0.2	0.2	0.2	0.2
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Calcium, mg/l	21	23	27	30	41	44	41	47
Chloride, mg/l	4	5	4	6	9	10	9	9
Chromium, mg/l	0.021	0.023	0.024	0.011	<0.005	<0.005	0.008	0.010
Conductivity, 25°C, umhos/cm	140	180	210	250	320	360	310	320
Copper, mg/l	0.19	0.12	0.14	0.14	0.08	0.01	0.04	0.09
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	69	76	91	100	140	150	90	150
Iron, mg/l	5.4	11	6.7	10	1.3	1.7	1.1	4.2
Lead, mg/l	0.02	0.031	<0.010	0.019	0.026	0.020	0.038	0.020
Magnesium, mg/l	4.1	4.4	5.7	6.0	8.0	9.3	6.8	7.7
Manganese, mg/l	0.17	0.16	0.25	0.26	0.10	0.07	0.08	0.12
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0006	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05
Phosphorous, mg/l	0.12	0.14	0.13	0.23	0.04	0.03	0.03	0.03
Selenium, mg/l	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	5.2	6.3	6.9	7.4	1.7	-	6.3	8.0
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	120	150	120	170	200	240	170	200
Solids, Suspended, mg/l	100	120	190	200	14	5	45	26
Sulfate, mg/l	6	41	28	48	24	42	15	43
Zinc, mg/l	0.09	0.14	0.12	0.16	0.08	0.07	0.06	0.15

Table A-2 (Continued)

TVA PLANT A RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/14/75		4/7/75		7/14/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	4.9	*	3.1	1.2	0.7	2.1	2.1
Ammonia as N, mg/l	NA	0.06	0.02	0.06	0.04	0.09	0.14	0.14
Arsenic, mg/l	NA	<0.005	<0.005	<0.005		<0.005	0.005	0.015
Barium, mg/l	NA	0.1	*	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	NA	<0.01	*	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	NA	<0.001	*	0.002	0.001	0.001	<0.001	0.002
Calcium, mg/l	NA	34	*	23	48	51	35	26
Chloride, mg/l	NA	5	4	4	5	6	10	7
Chromium, mg/l	NA	<0.005	*	0.005	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	NA	260	190	200	280	320	260	160
Copper, mg/l	NA	0.02	*	0.09	0.04	0.11	0.09	0.09
Cyanide, mg/l	NA	<0.01	–	–	–	–	–	–
Hardness, mg/l	NA	110	*	76	150	160	120	94
Iron, mg/l	NA	8.3	*	5.6	1.4	2.3	1.9	4.1
Lead, mg/l	NA	0.018	*	0.028	<0.010	<0.010	0.022	0.018
Magnesium, mg/l	NA	5.8	*	4.6	6.6	7.1	7.1	7.1
Manganese, mg/l	NA	0.24	*	0.13	0.10	0.12	0.12	0.25
Mercury, mg/l	NA	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	NA	<0.05	*	<0.05	0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	NA	0.08	0.05	0.02	0.14	0.02	0.06	0.05
Selenium, mg/l	NA	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.001
Silica, mg/l	NA	9.3	5.6	6.0	6.0	7.6	5.4	6.5
Silver, mg/l	NA	<0.01	*	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	NA	170	150	140	170	200	160	160
Solids, Suspended, mg/l	NA	110	21	21	18	6	33	14
Sulfate, mg/l	NA	29	28	40	18	63	21	23
Zinc, mg/l	NA	0.06	*	0.10	0.06	0.09	0.10	0.02

NA = Not Available
*Bottle Broken

Table A-2 (Continued)

TVA PLANT A RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/8/76		4/13/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	3.3	NA	2.0
Ammonia as N, mg/l	NA	0.06	NA	0.07
Arsenic, mg/l	NA	0.005	NA	<0.005
Barium, mg/l	NA	<0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	43	NA	38
Chloride, mg/l	NA	6	NA	6
Chromium, mg/l	NA	0.008	NA	<0.005
Conductivity, 25°C, umhos/cm	NA	280	NA	260
Copper, mg/l	NA	0.08	NA	0.09
Cyanide, mg/l	NA	–	NA	–
Hardness, mg/l	NA	130	NA	120
Iron, mg/l	NA	4.7	NA	4.4
Lead, mg/l	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	6.0	NA	6.3
Manganese, mg/l	NA	0.14	NA	0.15
Mercury, mg/l	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.07	NA	0.06
Selenium, mg/l	NA	<0.002	NA	<0.002
Silica, mg/l	NA	7.6	NA	6.3
Silver, mg/l	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	190	NA	160
Solids, Suspended, mg/l	NA	42	NA	33
Sulfate, mg/l	NA	45	NA	41
Zinc, mg/l	NA	0.12	NA	0.09

NA = Not Available
*Bottle Empty

Table A-3

TVA PLANT B RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/21/73		4/5/73		7/23/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.8	NA	0.7	NA	4.8	NA	2.6
Ammonia as N, mg/l	NA	0.11	NA	0.20	NA	0.08	NA	0.04
Arsenic, mg/l	NA	0.065	NA	0.050	NA	0.010	NA	0.005
Barium, mg/l	NA	0.1	NA	<0.1	NA	0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	0.002	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	250	NA	130	NA	430	NA	33
Chloride, mg/l	NA	7	NA	4	NA	6	NA	8
Chromium, mg/l	NA	0.036	NA	<0.005	NA	0.011	NA	<0.005
Conductivity, 25°C, umhos/cm	NA	940	NA	580	NA	2,200	NA	240
Copper, mg/l	NA	<0.01	NA	0.02	NA	0.02	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	650	NA	340	NA	1,100	NA	110
Iron, mg/l	NA	0.69	NA	7.1	NA	1.2	NA	4.2
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	6.8	NA	4.4	NA	0.2	NA	5.9
Manganese, mg/l	NA	0.04	NA	0.63	NA	0.04	NA	0.12
Mercury, mg/l	NA	0.0056	NA	0.0002	NA	0.0010	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.55	NA	0.24	NA	0.03	NA	0.18
Selenium, mg/l	NA	0.064	NA	0.007	NA	0.030	NA	<0.001
Silica, mg/l	NA	8.0	NA	22	NA	3.7	NA	6.0
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	760	NA	440	NA	1,100	NA	160
Solids, Suspended, mg/l	NA	13	NA	14	NA	28	NA	39
Sulfate, mg/l	NA	450	NA	230	NA	480	NA	44
Zinc, mg/l	NA	0.08	NA	0.04	NA	0.09	NA	0.03

NA = Not Available

Table A-3 (Continued)

TVA PLANT B RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	2/12/74		5/15/74	4/8/74	8/13/74	7/16/74	11/12/74	10/30/74
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.6	0.8	1.0	1.8	0.6	1.0	0.2	0.9
Ammonia as N, mg/l	0.04	0.09	0.05	<0.01	0.06	<0.01	0.04	0.02
Arsenic, mg/l	<0.005	0.010	<0.005	0.065	<0.005	0.055	<0.005	<0.005
Barium, mg/l	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.001
Calcium, mg/l	19	120	22	27	22	50	19	95
Chloride, mg/l	4	6	4	4	6	6	7	8
Chromium, mg/l	<0.005	0.017	<0.005	0.010	<0.005	<0.005	<0.005	0.034
Conductivity, 25°C, umhos/cm	150	550	150	200	170	67	-	620
Copper, mg/l	<0.01	<0.01	0.04	<0.05	<0.01	<0.01	<0.01	0.04
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	67	320	76	79	77	140	69	250
Iron, mg/l	0.9	1.1	0.47	0.66	0.44	0.26	0.36	0.19
Lead, mg/l	0.010	<0.010	<0.010	0.027	<0.010	0.024	<0.010	<0.010
Magnesium, mg/l	4.7	4.4	5.0	2.8	5.0	4.1	5.2	2.3
Manganese, mg/l	0.06	0.05	0.04	0.06	0.1	0.02	0.05	0.05
Mercury, mg/l	<0.0002	<0.0002	0.0009	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	0.08	<0.05	<0.005	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	-	0.10	0.03	0.13	0.04	0.10	0.02	<0.01
Selenium, mg/l	<0.001	0.004	<0.002	0.007	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	7.2	7.8	5.1	3.8	4.8	-	4.6	4.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	90	40	90	130	100	250	-	460
Solids, Suspended, mg/l	14	15	4	15	7	3	-	2
Sulfate, mg/l	12	190	11	35	14	110	14	230
Zinc, mg/l	0.02	0.02	<0.01	<0.01	0.01	0.13	<0.01	0.06

Table A-3 (Continued)

TVA PLANT B RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	2/4/75 River Intake	1/15/75 Pond Discharge	5/19/75 River Intake	4/21/75 Pond Discharge	8/5/75 River Intake	4/14/75 Pond Discharge	11/4/75 River Intake	10/14/75 Pond Discharge
Aluminum, mg/l	–	0.6	0.4	1.3	0.5	1.6	0.7	1.5
Ammonia as N, mg/l	0.08	0.09	0.08	0.11	0.05	0.02	0.04	0.06
Arsenic, mg/l	<0.005	<0.005	<0.005	0.005	<0.005	0.070	0.005	0.008
Barium, mg/l	–	0.2	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Beryllium, mg/l	–	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	0.003	<0.001	0.01	0.001	0.002	<0.001
Calcium, mg/l	17	110	20	220	–	190	16	170
Chloride, mg/l	6	7	4	7	7	6	7	7
Chromium, mg/l	<0.005	<0.005	<0.005	0.020	<0.005	0.006	<0.005	<0.005
Conductivity, 25°C, umhos/cm	160	650	150	880	–	790	140	730
Copper, mg/l	0.02	<0.01	<0.01	0.03	0.02	0.08	<0.01	0.10
Cyanide, mg/l	–	<0.01	–	–	–	–	–	–
Hardness, mg/l	57	290	67	550	–	480	56	450
Iron, mg/l	0.32	0.48	0.68	0.21	0.38	0.27	0.37	0.14
Lead, mg/l	–	0.014	<0.010	0.030	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	3.6	3.6	4.5	0.6	–	2.1	3.8	6.1
Manganese, mg/l	0.06	0.31	0.04	0.03	0.08	0.02	0.06	0.03
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	0.0120	<0.0002	0.0002
Nickel, mg/l	–	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.02	0.01	0.02	<0.01	0.02	0.04	0.01	0.04
Selenium, mg/l	<0.002	<0.002	<0.002	0.022	<0.002	0.018	<0.002	0.025
Silica, mg/l	5.6	5.9	3.2	7.2	5.6	6.5	4.8	3.1
Silver, mg/l	–	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	440	90	520	90	600	95	600
Solids, Suspended, mg/l	12	6	8	6	9	10	5	2
Sulfate, mg/l	18	160	9	300	10	17	10	320
Zinc, mg/l	0.04	0.04	<0.01	0.02	0.02	0.06	<0.01	0.03

Table A-4

TVA PLANT B RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/21/73		4/5/73		7/23/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.5	NA	2.2	NA	0.9	NA	4.1
Ammonia as N, mg/l	NA	0.09	NA	0.04	NA	0.01	NA	0.06
Arsenic, mg/l	NA	<0.005	NA	0.005	NA	0.010	NA	0.050
Barium, mg/l	NA	<0.1	NA	<0.1	NA	<0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	<0.001	NA	0.01
Calcium, mg/l	NA	24	NA	23	NA	30	NA	200
Chloride, mg/l	NA	7	NA	5	NA	6	NA	8
Chromium, mg/l	NA	<0.005	NA	<0.005	NA	<0.005	NA	0.026
Conductivity, 25°C, umhos/cm	NA	210	NA	180	NA	210	NA	750
Copper, mg/l	NA	<0.01	NA	0.03	NA	0.01	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	80	NA	78	NA	93	NA	520
Iron, mg/l	NA	3.2	NA	2.4	NA	1.8	NA	1.1
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	0.012
Magnesium, mg/l	NA	4.9	NA	5.1	NA	4.4	NA	4.8
Manganese, mg/l	NA	0.16	NA	0.12	NA	0.05	NA	0.07
Mercury, mg/l	NA	0.0026	NA	<0.0002	NA	0.0021	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.11	NA	0.18	NA	0.10	NA	0.36
Selenium, mg/l	NA	<0.001	NA	0.001	NA	–	NA	0.056
Silica, mg/l	NA	5.7	NA	5.6	NA	5.3	NA	3.7
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	110	NA	120	NA	130	NA	630
Solids, Suspended, mg/l	NA	20	NA	15	NA	10	NA	46
Sulfate, mg/l	NA	30	NA	25	NA	36	NA	350
Zinc, mg/l	NA	0.03	NA	0.02	NA	0.02	NA	0.09

NA = Not Available

Table A-4 (Continued)

TVA.PLANT B RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	2/12/74		5/15/74	4/8/74	8/13/74		11/12/74	10/30/74
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.6	3.7	1.0	8.6	0.6	NA	0.2	0.4
Ammonia as N, mg/l	0.04	0.08	0.05	0.31	0.06	NA	0.04	0.12
Arsenic, mg/l	<0.005	0.010	<0.005	<0.005	<0.005	NA	<0.005	<0.005
Barium, mg/l	<0.1	<0.1	<0.1	0.3	<0.1	NA	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	0.004	<0.001	NA	0.002	0.001
Calcium, mg/l	19	37	22	120	22	NA	19	16
Chloride, mg/l	4	8	4	11	6	NA	7	8
Chromium, mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	NA	<0.005	0.020
Conductivity, 25°C, umhos/cm	150	300	150	960	170	NA	–	220
Copper, mg/l	<0.01	0.04	0.04	0.18	<0.01	NA	<0.01	0.04
Cyanide, mg/l	–	<0.01	–	<0.01	–	NA	–	–
Hardness, mg/l	67	120	76	390	77	NA	69	57
Iron, mg/l	0.9	8.0	0.47	30	0.44	NA	0.36	1.1
Lead, mg/l	0.010	<0.010	<0.010	0.048	<0.010	NA	<0.010	<0.010
Magnesium, mg/l	4.7	7.0	5.0	21	5.0	NA	5.2	4.2
Manganese, mg/l	0.06	0.54	0.04	3.6	0.1	NA	0.05	0.04
Mercury, mg/l	<0.0002	<0.0002	0.0009	<0.0002	<0.0002	NA	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	0.14	<0.05	NA	<0.05	<0.05
Phosphorous, mg/l	–	0.12	0.03	0.08	0.04	NA	0.02	0.04
Selenium, mg/l	0.001	0.014	<0.002	<0.002	<0.002	NA	<0.002	<0.002
Silica, mg/l	7.2	6.7	5.1	22	4.8	NA	4.6	4.8
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.01	<0.01
Solids, Dissolved, mg/l	90	190	90	710	100	NA	–	120
Solids, Suspended, mg/l	14	48	4	78	7	NA	–	4
Sulfate, mg/l	12	71	11	470	14	NA	14	22
Zinc, mg/l	0.02	0.24	<0.01	0.55	0.01	NA	<0.01	0.06

NA = Not Available

Table A-4 (Continued)

TVA PLANT B RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	2/4/75	1/15/75	5/19/75	4/21/75	8/5/75	7/14/75	11/4/75	10/14/75
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	–	1.2	0.4	1.4	0.5	0.6	0.7	0.5
Ammonia as N, mg/l	0.08	0.04	0.08	0.06	0.05	0.05	0.04	<0.01
Arsenic, mg/l	<0.0005	<0.0005	<0.005	<0.005	<0.005	<0.005	0.005	0.008
Barium, mg/l	–	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
Beryllium, mg/l	–	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	0.003	<0.001	0.01	0.001	0.002	<0.001
Calcium, mg/l	17	30	20	17	–	26	16	23
Chloride, mg/l	6	8	4	5	7	6	7	7
Chromium, mg/l	<0.005	0.008	<0.005	0.012	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	160	250	150	190	–	160	140	190
Copper, mg/l	0.02	0.20	<0.01	0.03	0.02	0.08	<0.01	0.06
Cyanide, mg/l	–	<0.01	–	–	–	–	–	–
Hardness, mg/l	57	93	67	60	–	85	56	79
Iron, mg/l	0.32	2.1	0.68	2.5	0.38	2.2	0.37	1.7
Lead, mg/l	–	0.042	<0.010	0.024	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	3.6	4.5	4.5	4.3	–	4.9	3.8	5.2
Manganese, mg/l	0.06	0.13	0.04	0.09	0.08	0.08	0.06	0.09
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.042	<0.0002	<0.0002	<0.0002	0.0002
Nickel, mg/l	–	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.02	0.03	0.02	0.03	0.02	0.04	0.01	0.03
Selenium, mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	5.6	6.9	3.2	6.1	5.6	4.5	4.8	5.0
Silver, mg/l	–	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	140	90	120	90	120	95	110
Solids, Suspended, mg/l	12	23	8	13	9	16	5	2
Sulfate, mg/l	18	35	9	26	10	20	10	25
Zinc, mg/l	0.04	0.12	<0.01	0.11	0.02	0.12	<0.01	0.03

Table A-5

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (EAST) DISCHARGE DATA
(Quarterly Samples)

Date	1/73		4/3/73		7/3/73		9/30/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.8	NA	3.8	NA	2.7	NA	0.3
Ammonia as N, mg/l	NA	0.23	NA	0.12	NA	0.09	NA	0.04
Arsenic, mg/l	NA	0.008	NA	0.010	NA	0.015	NA	0.050
Barium, mg/l	NA	<0.1	NA	0.2	NA	0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	0.002	NA	0.004	NA	0.002	NA	0.003
Calcium, mg/l	NA	45	NA	86	NA	94	NA	100
Chloride, mg/l	NA	8	NA	11	NA	12	NA	16
Chromium, mg/l	NA	<0.005	NA	0.008	NA	<0.005	NA	<0.005
Conductivity, 25°C, umhos/cm	NA	380	NA	470	NA	430	NA	620
Copper, mg/l	NA	0.01	NA	<0.01	NA	0.02	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	140	NA	250	NA	290	NA	320
Iron, mg/l	NA	2.0	NA	4.1	NA	2.5	NA	0.34
Lead, mg/l	NA	<0.010	NA	0.069	NA	<0.010	NA	0.012
Magnesium, mg/l	NA	7.1	NA	9.4	NA	14	NA	16
Manganese, mg/l	NA	0.13	NA	0.27	NA	0.16	NA	0.25
Mercury, mg/l	NA	0.0025	NA	0.0006	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.21	NA	0.24	NA	0.15	NA	0.21
Selenium, mg/l	NA	0.080	NA	–	NA	0.004	NA	<0.001
Silica, mg/l	NA	6.4	NA	7.5	NA	4.7	NA	8.0
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	260	NA	310	NA	300	NA	460
Solids, Suspended, mg/l	NA	17	NA	37	NA	25	NA	4
Sulfate, mg/l	NA	120	NA	130	NA	110	NA	170
Zinc, mg/l	NA	0.09	NA	0.08	NA	0.10	NA	0.02

NA = Not Available

Table A-5 (Continued)

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (EAST) DISCHARGE DATA
(Quarterly Samples)

Date	1/15/74		4/9/74		7/16/74		10/18/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.4	2.4	3.7	1.1	4.9	1.9	1.9	0.3
Ammonia as N, mg/l	0.28	0.23	0.03	0.02	0.12	0.08	0.29	0.07
Arsenic, mg/l	0.010	0.005	<0.005	0.010	<0.005	0.005	<0.005	<0.005
Barium, mg/l	0.1	0.2	0.2	0.4	0.2	0.3	0.2	0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.010	<0.001	0.010	<0.001	0.006	<0.001	0.004
Calcium, mg/l	15	80	29	70	28	83	38	100
Chloride, mg/l	9	9	12	12	10	10	16	15
Chromium, mg/l	0.041	0.008	<0.005	<0.005	<0.005	<0.005	0.016	<0.010
Conductivity, 25°C, umhos/cm	170	510	310	560	300	580	410	600
Copper, mg/l	0.22	<0.01	0.12	0.10	0.15	0.07	0.06	0.04
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	65	230	110	180	110	250	150	310
Iron, mg/l	14	3.3	3.7	1.6	6.1	2.7	2.4	0.33
Lead, mg/l	0.032	0.024	0.02	<0.010	0.022	0.020	0.010	0.020
Magnesium, mg/l	6.8	7.2	9.4	1.4	9.8	11	14	14
Manganese, mg/l	0.34	0.25	0.12	0.34	0.38	0.18	0.53	0.19
Mercury, mg/l	<0.0002	0.11	<0.0002	0.0074	0.0016	<0.0002	<0.0002	<0.0002
Nickel, mg/l	0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.49	0.02	0.28	0.02	0.29	-	0.06	<0.01
Selenium, mg/l	0.004	0.010	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	7.1	7.2	7.9	8.7	-	-	5.4	6.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
Solids, Dissolved, mg/l	170	330	160	350	200	-	240	400
Solids, Suspended, mg/l	38	32	32	22	31	24	39	3
Sulfate, mg/l	48	190	44	190	40	160	52	170
Zinc, mg/l	0.13	0.25	0.08	0.22	0.03	0.11	0.06	0.08

Table A-5 (Continued)

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (EAST) DISCHARGE DATA
(Quarterly Samples)

Date	1/14/75		4/8/75		7/15/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	15	0.4	8.5	1.0	1.3	0.6	0.6	1.4
Ammonia as N, mg/l	0.33	0.34	0.03	0.04	0.03	0.06	0.03	0.05
Arsenic, mg/l	<0.005	<0.005	<0.005	0.005	0.026	0.032	<0.005	0.010
Barium, mg/l	0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.007	0.002	0.013	<0.001	0.003	<0.001	0.002
Calcium, mg/l	20	59	17	88	43	68	45	66
Chloride, mg/l	9	9	7	7	11	12	15	16
Chromium, mg/l	<0.005	<0.005	0.013	<0.005	0.009	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	20	480	200	480	360	5200	400	530
Copper, mg/l	0.03	0.04	0.13	0.09	0.10	0.05	0.09	0.07
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	80	180	69	250	160	220	150	230
Iron, mg/l	13	0.49	10	1.4	1.4	1.1	1.0	2.3
Lead, mg/l	0.028	0.030	0.047	0.021	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	7.4	7.8	6.5	7.0	12	13	10	15
Manganese, mg/l	0.26	0.13	0.29	0.17	0.26	0.14	0.29	0.14
Mercury, mg/l	<0.0002	0.0220	<0.0002	No Bottle	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.27	0.02	0.23	0.02	0.10	0.05	0.07	0.07
Selenium, mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.002
Silica, mg/l	5.6	6.7	5.8	7.8	5.6	11	5.5	6.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	200	320	190	340	220	340	260	380
Solids, Suspended, mg/l	150	5	48	12	17	4	11	25
Sulfate, mg/l	54	180	68	200	34	130	68	140
Zinc, mg/l	0.10	0.14	0.10	0.27	0.08	0.04	0.07	0.07

Table A-5 (Continued)

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (EAST) DISCHARGE DATA
(Quarterly Samples)

Date	1/8/76		4/13/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.2	1.2	1.1	2.3
Ammonia as N, mg/l	0.15	0.20	0.03	0.06
Arsenic, mg/l	<0.005	0.010	0.005	<0.010
Barium, mg/l	<0.1	0.2	<0.1	0.3
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.013	<0.001	0.010
Calcium, mg/l	35	61	24	43
Chloride, mg/l	13	12	8	9
Chromium, mg/l	<0.005	0.018	<0.005	<0.005
Conductivity, 25°C, umhos/cm	300	440	210	450
Copper, mg/l	0.09	0.05	0.05	0.19
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	120	190	87	160
Iron, mg/l	3.7	1.9	1.8	3.4
Lead, mg/l	<0.010	<0.010	<0.010	0.014
Magnesium, mg/l	8.6	9.5	6.6	13
Manganese, mg/l	0.09	0.13	0.10	0.16
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.20	0.57	0.33	0.05
Selenium, mg/l	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	7.3	7.1	10.0	9.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	130	310	170	300
Solids, Suspended, mg/l	32	20	58	18
Sulfate, mg/l	25	130	50	140
Zinc, mg/l	0.03	0.33	0.02	0.23

Table A-6

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (WEST) DISCHARGE DATA
(Quarterly Samples)

Date	1/73		4/73		7/3/73		9/30/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	6.9	NA	*	NA	0.8	NA	1.2
Ammonia as N, mg/l	NA	0.07	NA	*	NA	0.02	NA	0.02
Arsenic, mg/l	NA	0.008	NA	*	NA	0.010	NA	0.035
Barium, mg/l	NA	<0.1	NA	*	NA	<0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	*	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	*	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	26	NA	*	NA	32	NA	40
Chloride, mg/l	NA	8	NA	*	NA	10	NA	14
Chromium, mg/l	NA	<0.005	NA	*	NA	<0.005	NA	0.005
Conductivity, 25°C, umhos/cm	NA	250	NA	*	NA	300	NA	380
Copper, mg/l	NA	<0.01	NA	*	NA	0.02	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	*	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	92	NA	*	NA	130	NA	170
Iron, mg/l	NA	5.7	NA	*	NA	0.76	NA	0.97
Lead, mg/l	NA	<0.010	NA	*	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	6.6	NA	*	NA	12	NA	16
Manganese, mg/l	NA	0.15	NA	*	NA	0.09	NA	0.05
Mercury, mg/l	NA	0.0002	NA	*	NA	<0.011	NA	0.0002
Nickel, mg/l	NA	<0.05	NA	*	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.57	NA	*	NA	0.21	NA	0.32
Selenium, mg/l	NA	<0.004	NA	*	NA	0.004	NA	<0.001
Silica, mg/l	NA	6.9	NA	*	NA	1.5	NA	2.7
Silver, mg/l	NA	<0.01	NA	*	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	170	NA	*	NA	180	NA	250
Solids, Suspended, mg/l	NA	57	NA	*	NA	11	NA	24
Sulfate, mg/l	NA	70	NA	*	NA	35	NA	60
Zinc, mg/l	NA	0.16	NA	*	NA	0.04	NA	0.03

NA = Not Available
*Sample not collected due to high water of Mississippi River.

Table A-6 (Continued)

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (WEST) DISCHARGE DATA
(Quarterly Samples)

Date	1/15/74		4/9/74		7/16/74		10/8/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.4	6.6	3.7	2.4	4.9	1.6	1.9	0.5
Ammonia as N, mg/l	0.28	0.18	0.03	<0.02	0.12	0.11	0.29	0.10
Arsenic, mg/l	0.010	0.010	<0.005	<0.005	<0.005	0.11	<0.005	<0.005
Barium, mg/l	0.1	0.1	0.2	0.3	0.2	0.2	0.2	0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.004
Calcium, mg/l	15	19	70	26	28	27	38	89
Chloride, mg/l	9	10	12	11	10	10	16	14
Chromium, mg/l	0.041	0.014	<0.005	0.010	<0.005	<0.005	0.016	0.008
Conductivity, 25°C, umhos/cm	170	230	310	320	300	270	410	600
Copper, mg/l	0.22	<0.01	0.12	0.12	0.15	0.10	0.06	0.06
Cyanide, mg/l	–	0.01	–	<0.01	–	<0.01	–	–
Hardness, mg/l	65	73	110	100	110	100	150	280
Iron, mg/l	14	7.8	3.7	2.8	6.1	2.0	2.4	0.72
Lead, mg/l	0.032	0.033	0.02	<0.010	0.022	0.024	0.010	0.016
Magnesium, mg/l	6.8	6.3	9.4	8.9	9.8	9.0	14	14
Manganese, mg/l	0.34	0.20	0.12	0.07	0.38	0.11	0.53	0.34
Mercury, mg/l	<0.0002	0.0003	<0.0002	0.0041	0.0016	0.050	<0.0002	<0.0002
Nickel, mg/l	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.49	0.30	0.28	0.13	0.29	–	0.06	0.02
Selenium, mg/l	0.004	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	7.1	6.7	7.9	8.2	–	–	5.4	5.9
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Solids, Dissolved, mg/l	170	180	160	170	200	–	240	390
Solids, Suspended, mg/l	38	27	32	29	31	19	39	4
Sulfate, mg/l	48	80	44	50	40	42	52	180
Zinc, mg/l	0.13	0.15	0.08	0.14	0.03	0.11	0.06	0.11

Table A-6 (Continued)

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (WEST) DISCHARGE DATA
(Quarterly Samples)

Date	1/14/75		4/22/75		7/15/75			
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	15.0	8.0	8.5	3.2	1.3	2.3	Pond not in service. No sample collected.	
Ammonia as N, mg/l	0.33	0.22	0.03	0.11	0.03	0.12		
Arsenic, mg/l	<0.005	<0.005	<0.005	0.005	0.026	0.028		
Barium, mg/l	0.1	0.2	<0.1	<0.1	<0.1	<0.1		
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
Cadmium, mg/l	<0.001	0.001	0.002	<0.001	<0.001	0.010		
Calcium, mg/l	20	26	17	23	43	57		
Chloride, mg/l	9	9	7	8	11	11		
Chromium, mg/l	<0.005	<0.005	0.013	0.011	0.009	0.024		
Conductivity, 25°C, umhos/cm	20	260	200	320	360	630		
Copper, mg/l	0.03	0.02	0.13	0.04	0.10	0.18		
Cyanide, mg/l	-	<0.01	-	-	-	-		
Hardness, mg/l	80	95	69	85	160	200		
Iron, mg/l	13	8.5	10	3.3	1.4	24		
Lead, mg/l	0.028	0.030	0.047	<0.010	<0.010	0.015		
Magnesium, mg/l	7.4	7.2	6.5	6.7	12	13		
Manganese, mg/l	0.26	0.16	0.29	0.20	0.26	0.66		
Mercury, mg/l	<0.0002	*	<0.0002	<0.0002	<0.0002	<0.0002		
Nickel, mg/l	<0.05	<0.05	<0.05	0.06	<0.05	0.17		
Phosphorous, mg/l	0.27	0.20	0.23	0.08	0.10	0.01		
Selenium, mg/l	<0.002	<0.002	<0.002	0.003	<0.002	0.003		
Silica, mg/l	5.6	5.7	5.8	8.6	5.6	14		
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
Solids, Dissolved, mg/l	200	190	190	200	220	420		
Solids, Suspended, mg/l	150	98	48	24	17	13		
Sulfate, mg/l	54	65	68	130	34	280		
Zinc, mg/l	0.10	0.14	0.10	0.13	0.08	0.43		

*Sample received broken.

Table A-6 (Continued)

TVA PLANT C RIVER WATER INTAKE AND COMBINED ASH POND (WEST) DISCHARGE DATA
(Quarterly Samples)

Date	1/8/76	
	River Intake	Pond Discharge
Aluminum, mg/l	1.2	1.2
Ammonia as N, mg/l	0.15	0.20
Arsenic, mg/l	<0.005	0.010
Barium, mg/l	<0.1	0.2
Beryllium, mg/l	<0.01	<0.01
Cadmium, mg/l	<0.001	0.013
Calcium, mg/l	35	61
Chloride, mg/l	13	12
Chromium, mg/l	<0.005	0.018
Conductivity, 25°C, umhos/cm	300	440
Copper, mg/l	0.09	0.05
Cyanide, mg/l	-	-
Hardness, mg/l	120	190
Iron, mg/l	3.7	1.9
Lead, mg/l	<0.010	<0.010
Magnesium, mg/l	8.6	9.5
Manganese, mg/l	0.09	0.13
Mercury, mg/l	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05
Phosphorous, mg/l	0.20	0.07
Selenium, mg/l	<0.002	<0.002
Silica, mg/l	7.3	7.1
Silver, mg/l	<0.01	<0.01
Solids, Dissolved, mg/l	130	310
Solids, Suspended, mg/l	32	20
Sulfate, mg/l	25	130
Zinc, mg/l	0.03	0.33

Table A-7

TVA PLANT D RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/2/73		4/2/73		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.1	NA	1.3	NA	0.4	NA	2.6
Ammonia as N, mg/l	NA	0.15	NA	0.11	NA	0.01	NA	0.01
Arsenic, mg/l	NA	0.018	NA	0.025	NA	0.020	NA	0.050
Barium, mg/l	NA	0.2	NA	0.2	NA	0.2	NA	0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	0.001	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	37	NA	33	NA	28	NA	34
Chloride, mg/l	NA	5	NA	4	NA	3	NA	3
Chromium, mg/l	NA	<0.005	NA	<0.005	NA	<0.005	NA	0.005
Conductivity, 25°C, umhos/cm	NA	310	NA	280	NA	210	NA	250
Copper, mg/l	NA	<0.01	NA	<0.01	NA	0.01	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	130	NA	120	NA	100	NA	110
Iron, mg/l	NA	0.17	NA	0.27	NA	0.08	NA	0.39
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	9.0	NA	8.4	NA	7.8	NA	8.9
Manganese, mg/l	NA	0.04	NA	0.05	NA	0.01	NA	0.02
Mercury, mg/l	NA	0.001	NA	0.0002	NA	0.0003	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	0.19
Phosphorous, mg/l	NA	0.07	NA	0.04	NA	0.06	NA	0.15
Selenium, mg/l	NA	0.140	NA	>0.050	NA	0.050	NA	0.056
Silica, mg/l	NA	3.2	NA	3.8	NA	1.0	NA	5.0
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	200	NA	100	NA	120	NA	170
Solids, Suspended, mg/l	NA	8	NA	14	NA	3	NA	33
Sulfate, mg/l	NA	84	NA	60	NA	35	NA	52
Zinc, mg/l	NA	0.01	NA	0.01	NA	<0.01	NA	0.01

NA = Not Available

Table A-7 (Continued)

TVA PLANT D RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/15/74		4/22/74		7/16/74		10/7/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.9	0.3	0.2	2.9	0.4	0.6	0.4	1.8
Ammonia as N, mg/l	0.01	0.14	<0.01	<0.01	0.01	0.06	0.13	0.04
Arsenic, mg/l	<0.005	0.010	<0.005	0.045	<0.005	0.025	<0.005	0.050
Barium, mg/l	0.2	<0.1	0.2	0.3	0.2	0.2	0.1	0.2
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Calcium, mg/l	27	26	28	30	26	31	31	34
Chloride, mg/l	4	4	3	4	3	3	3	3
Chromium, mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008
Conductivity, 25°C, umhos/cm	150	920	200	240	220	270	240	300
Copper, mg/l	0.22	<0.01	0.03	0.04	0.02	<0.01	0.04	0.04
Cyanide, mg/l	–	<0.01	–	<0.01	–	<0.01	–	–
Hardness, mg/l	100	96	100	110	97	110	110	120
Iron, mg/l	1.00	0.14	0.41	0.55	0.57	0.15	0.33	0.28
Lead, mg/l	0.016	<0.010	<0.010	<0.010	<0.010	0.020	<0.010	0.016
Magnesium, mg/l	8.4	7.5	7.7	7.6	7.8	8.1	8.8	8.8
Manganese, mg/l	0.10	0.05	0.03	0.02	0.05	<0.01	0.13	0.02
Mercury, mg/l	0.0005	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	0.27	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	<0.01	<0.01	0.02	0.02	0.01	–	0.01	0.08
Selenium, mg/l	0.004	0.098	<0.002	<0.002	<0.002	0.110	<0.002	0.016
Silica, mg/l	3.8	3.6	4.4	4.4	–	–	4.7	4.8
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	130	160	120	150	120	–	130	180
Solids, Suspended, mg/l	13	7	8	45	10	6	6	19
Sulfate, mg/l	14	70	16	16	13	80	14	72
Zinc, mg/l	0.07	<0.01	0.07	0.07	0.03	0.06	0.03	0.04

Table A-7 (Continued)

TVA PLANT D RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/13/75		4/7/75		7/14/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	*	0.6	0.5	3.8	0.7	1.6	0.5	<0.2
Ammonia as N, mg/l	0.06	0.04	0.04	0.04	0.02	0.02	0.07	0.04
Arsenic, mg/l	<0.005	<0.005	<0.005	0.055	<0.005	0.100	<0.005	<0.005
Barium, mg/l	*	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	*	0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001
Calcium, mg/l	*	33	23	26	29	32	30	31
Chloride, mg/l	3	3	3	3	2	2	*	3
Chromium, mg/l	*	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	220	280	220	260	200	250	*	260
Copper, mg/l	*	0.01	0.06	0.05	0.05	0.14	0.09	0.07
Cyanide, mg/l	–	<0.01	–	–	–	–	–	–
Hardness, mg/l	*	120	87	96	100	110	110	120
Iron, mg/l	*	0.09	0.47	0.67	0.56	<0.05	0.25	0.33
Lead, mg/l	*	0.046	0.018	0.028	<0.010	<0.010	0.011	<0.010
Magnesium, mg/l	*	8.3	7.2	7.5	7.1	8.2	9.1	9.8
Manganese, mg/l	*	0.03	0.05	0.03	0.07	0.02	0.09	0.04
Mercury, mg/l	*	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	*	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.05	0.02	0.01	0.07	0.04	0.03	0.02	0.02
Selenium, mg/l	<0.002	0.130	<0.002	0.170	<0.002	0.010	<0.002	0.010
Silica, mg/l	4.4	3.3	5.2	5.0	9.5	6.2	4.5	4.3
Silver, mg/l	*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	140	170	130	160	110	150	*	160
Solids, Suspended, mg/l	55	6	6	31	1	8	*	4
Sulfate, mg/l	18	65	20	58	15	60	*	31
Zinc, mg/l	*	0.04	0.03	0.05	0.03	0.03	0.04	0.03

*Bottle received broken.

Table A-7 (Continued)

TVA PLANT D RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/12/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.2	0.8	0.5	0.3
Ammonia as N, mg/l	0.02	0.12	0.03	0.09
Arsenic, mg/l	<0.005	0.025	<0.005	0.030
Barium, mg/l	<0.1	<0.1	<0.1	0.5
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.001	<0.001	<0.001
Calcium, mg/l	32	50	34	55
Chloride, mg/l	4	4	4	4
Chromium, mg/l	<0.005	0.012	<0.005	<0.005
Conductivity, 25°C, umhos/cm	240	340	240	370
Copper, mg/l	<0.01	<0.01	0.01	0.03
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	110	160	120	170
Iron, mg/l	0.18	0.29	0.36	0.32
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	8.5	8.8	8.6	8.5
Manganese, mg/l	0.04	0.08	0.07	0.02
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.01	0.04	0.02	0.03
Selenium, mg/l	<0.002	0.026	<0.002	0.020
Silica, mg/l	2.3	3.9	3.0	3.2
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	130	220	110	230
Solids, Suspended, mg/l	4	10	1	3
Sulfate, mg/l	19	89	11	120
Zinc, mg/l	0.02	<0.01	0.05	0.01

Table A-8

TVA PLANT E RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/4/73		4/2/73		7/3/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.5	NA	11	NA	2.9	NA	3.4
Ammonia as N, mg/l	NA	0.07	NA	0.08	NA	0.07	NA	0.23
Arsenic, mg/l	NA	0.005	NA	0.010	NA	0.010	NA	0.005
Barium, mg/l	NA	0.1	NA	0.4	NA	0.2	NA	0.4
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	0.002	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	230	NA	340	NA	210	NA	300
Chloride, mg/l	NA	8	NA	6	NA	5	NA	8
Chromium, mg/l	NA	0.015	NA	0.026	NA	0.027	NA	0.020
Conductivity, 25°C, umhos/cm	NA	1,200	NA	1,400	NA	950	NA	1,600
Copper, mg/l	NA	<0.01	NA	<0.01	NA	0.01	NA	0.20
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	580	NA	850	NA	530	NA	800
Iron, mg/l	NA	0.17	NA	3.6	NA	0.29	NA	0.20
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	0.6	NA	0.9	NA	0.5	NA	11
Manganese, mg/l	NA	<0.01	NA	0.06	NA	<0.01	NA	<0.01
Mercury, mg/l	NA	0.0002	NA	0.0002	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.06	NA	0.03	NA	0.04	NA	<0.03
Selenium, mg/l	NA	0.008	NA	0.024	NA	0.010	NA	0.016
Silica, mg/l	NA	5.0	NA	5.0	NA	6.2	NA	5.7
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	540	NA	680	NA	420	NA	680
Solids, Suspended, mg/l	NA	6	NA	150	NA	6	NA	8
Sulfate, mg/l	NA	180	NA	230	NA	22	NA	220
Zinc, mg/l	NA	0.07	NA	0.11	NA	0.02	NA	0.01

NA = Not Available

Table A-8 (Continued)

TVA PLANT E RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/15/74		4/9/74		7/16/74		10/16/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	2.7	2.0	3.2	4.5	0.6	1.3	0.5	2.1
Ammonia as N, mg/l	0.06	0.06	0.06	0.06	0.07	0.05	–	0.03
Arsenic, mg/l	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
Barium, mg/l	0.2	<0.1	<0.1	0.4	0.2	0.3	<0.1	0.3
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.001	<0.001
Calcium, mg/l	17	160	19	200	17	64	20	98
Chloride, mg/l	5	5	5	6	6	4	9	9
Chromium, mg/l	0.02	0.011	<0.005	0.039	–	–	<0.005	0.017
Conductivity, 25°C, umhos/cm	130	270	160	1,500	160	660	180	670
Copper, mg/l	0.13	<0.01	0.11	0.10	0.06	0.07	0.12	0.10
Cyanide, mg/l	–	<0.01	–	<0.01	–	<0.01	–	–
Hardness, mg/l	57	400	61	500	58	160	68	250
Iron, mg/l	2.40	0.16	0.94	0.95	–	–	0.18	0.20
Lead, mg/l	0.016	0.008	<0.01	<0.010	0.024	0.068	0.010	0.012
Magnesium, mg/l	3.6	0.2	3.4	0.3	3.9	1.1	4.5	0.3
Manganese, mg/l	0.1	<0.1	0.24	0.02	0.05	<0.01	0.07	0.02
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	0.0006	0.0003	<0.0002	–
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.08	<0.01	0.08	0.02	0.05	–	0.09	0.01
Selenium, mg/l	<0.001	0.020	<0.002	0.011	–	–	<0.002	<0.002
Silica, mg/l	5.2	5.6	4.4	5.0	–	–	5.8	6.9
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	80	310	90	580	–	–	110	260
Solids, Suspended, mg/l	9	10	27	37	4	23	2	5
Sulfate, mg/l	15	150	20	170	–	–	12	70
Zinc, mg/l	0.08	<0.01	0.08	0.08	0.07	0.07	0.05	0.06

Table A-8 (Continued)

TVA PLANT E RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/14/75		4/7/75		7/14/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	4.3	1.1	3.6	3.0	1.7	2.9	1.9	2.4
Ammonia as N, mg/l	0.07	0.05	0.07	0.09	0.04	0.04	0.10	0.05
Arsenic, mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	0.010	<0.005	0.130
Barium, mg/l	<0.1	<0.1	0.2	0.3	0.2	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001
Calcium, mg/l	18	68	14	170	20	140	16	130
Chloride, mg/l	6	7	4	5	5	5	6	8
Chromium, mg/l	<0.005	0.020	<0.005	0.020	<0.005	0.021	<0.005	<0.005
Conductivity, 25°C, umhos/cm	160	420	140	690	160	840	150	680
Copper, mg/l	0.02	0.02	0.03	0.02	0.08	0.19	0.07	0.11
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	57	170	48	430	67	350	54	330
Iron, mg/l	1.6	0.07	1.2	0.05	0.57	0.39	0.45	0.28
Lead, mg/l	0.028	0.022	<0.010	0.015	<0.010	<0.010	0.010	<0.010
Magnesium, mg/l	3.0	0.3	3.1	0.4	4.1	0.1	3.4	0.3
Manganese, mg/l	0.06	<0.01	0.04	<0.01	0.07	<0.01	0.04	0.02
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.09	0.01	0.06	0.01	0.07	<0.01	0.09	0.01
Selenium, mg/l	<0.002	<0.002	<0.002	0.014	<0.002	0.008	<0.001	0.010
Silica, mg/l	4.7	5.9	5.0	6.9	4.6	8.4	4.5	7.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	240	80	350	90	420	100	420
Solids, Suspended, mg/l	38	3	8	6	11	5	16	3
Sulfate, mg/l	25	100	20	170	19	130	15	130
Zinc, mg/l	0.04	0.03	0.18	0.07	0.04	0.03	0.07	0.04

Table A-8 (Continued)

TVA PLANT E RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/19/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	2.1	1.5	1.4	1.0
Ammonia as N, mg/l	0.13	0.09	0.10	0.84
Arsenic, mg/l	<0.005	<0.010	<0.005	0.010
Barium, mg/l	<0.1	0.3	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.010
Calcium, mg/l	22	140	26	110
Chloride, mg/l	7	6	6	6
Chromium, mg/l	<0.005	0.013	<0.005	0.007
Conductivity, 25°C, umhos/cm	150	650	180	600
Copper, mg/l	<0.01	<0.01	0.02	0.02
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	69	350	79	280
Iron, mg/l	0.45	0.18	0.40	0.17
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	3.5	0.3	3.5	0.1
Manganese, mg/l	0.04	<0.01	0.04	0.02
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0003
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.08	0.02	0.06	0.01
Selenium, mg/l	<0.002	<0.002	<0.002	0.005
Silica, mg/l	4.9	7.3	3.7	7.0
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	280	90	280
Solids, Suspended, mg/l	14	18	10	2
Sulfate, mg/l	14	83	19	93
Zinc, mg/l	<0.01	<0.01	<0.01	0.09

Table A-9

TVA PLANT F RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/1/73		3/28/73		7/13/73		10/16/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.0	NA	2.2	NA	1.8	NA	2.5
Ammonia as N, mg/l	NA	0.06	NA	0.03	NA	0.06	NA	0.12
Arsenic, mg/l	NA	<0.005	NA	0.005	NA	<0.005	NA	<0.005
Barium, mg/l	NA	<0.1	NA	<0.1	NA	<0.1	NA	0.3
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	100	NA	74	NA	140	NA	140
Chloride, mg/l	NA	5	NA	5	NA	4	NA	6
Chromium, mg/l	NA	0.030	NA	0.012	NA	0.059	NA	0.040
Conductivity, 25°C, umhos/cm	NA	410	NA	350	NA	650	NA	700
Copper, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	0.02
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	260	NA	200	NA	350	NA	380
Iron, mg/l	NA	0.19	NA	1.1	NA	<0.05	NA	<0.05
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	3.1	NA	2.7	NA	0.3	NA	7.2
Manganese, mg/l	NA	<0.01	NA	0.04	NA	<0.01	NA	<0.01
Mercury, mg/l	NA	0.0009	NA	<0.0002	NA	0.0003	NA	0.0003
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.14	NA	0.24	NA	0.03	NA	0.03
Selenium, mg/l	NA	0.024	NA	0.009	NA	0.016	NA	0.010
Silica, mg/l	NA	4.8	NA	4.2	NA	5.9	NA	7.6
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	320	NA	230	NA	390	NA	380
Solids, Suspended, mg/l	NA	1	NA	20	NA	2	NA	2
Sulfate, mg/l	NA	140	NA	120	NA	180	NA	230
Zinc, mg/l	NA	0.03	NA	0.01	NA	<0.01	NA	<0.01

NA = Not Available

Table A-9 (Continued)

TVA PLANT F RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	2/27/74	1/28/74	4/16/74		7/15/74		10/22/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	3.6	0.8	1.3	1.4	NA	3.1	<0.1	3.0
Ammonia as N, mg/l	0.03	0.38	0.03	0.26	NA	0.10	0.26	0.17
Arsenic, mg/l	<0.005	<0.005	<0.005	<0.005	NA	<0.005	<0.006	<0.005
Barium, mg/l	<0.10	<0.1	0.2	0.5	NA	0.1	<0.1	0.4
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.91	NA	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	NA	0.002	<0.001	<0.001
Calcium, mg/l	26	80	23	98	NA	130	35	160
Chloride, mg/l	4	4	3	5	NA	4	4	5
Chromium, mg/l	<0.005	0.050	0.012	0.040	NA	0.044	<0.005	0.072
Conductivity, 25°C, umhos/cm	170	480	150	500	NA	1,100	250	780
Copper, mg/l	<0.01	0.04	0.07	0.04	NA	<0.01	0.02	0.01
Cyanide, mg/l	-	<0.01	-	<0.01	NA	<0.01	-	-
Hardness, mg/l	81	200	75	250	NA	330	100q	400
Iron, mg/l	1.1	0.11	1.4	0.13	NA	<0.05	0.36	0.23
Lead, mg/l	<0.010	<0.010	0.032	<0.010	NA	0.040	<0.010	<0.010
Magnesium, mg/l	4.0	1.2	4.3	0.7	NA	0.2	4.2	0.2
Manganese, mg/l	0.06	<0.01	0.08	<0.01	NA	<0.01	0.03	<0.01
Mercury, mg/l	0.0033	<0.0002	<0.0002	<0.0002*	NA	0.3	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.10	0.03	0.11	0.02	NA	<0.01	0.15	<0.01
Selenium, mg/l	<0.002	0.012	<0.002	0.018	NA	0.028	<0.002	0.012
Silica, mg/l	5.4	6.0	4.9	6.8	NA		4.5	7.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	NA	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	90	280	110	350	NA	540	150	450
Solids, Suspended, mg/l	26	<1	28	2	NA	2	6	<1
Sulfate, mg/l	20	120	19	14	NA	200	19	240
Zinc, mg/l	0.18	0.08	0.22	0.06	NA	0.03	0.13	0.06

NA = Not Available
*Collected 4/22/74.

Table A-9 (Continued)

TVA PLANT F RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/20/75		4/7/75		7/15/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.3	1.5	2.3	0.9	1.0	1.0	<0.2	1.4
Ammonia as N, mg/l	0.03	0.30	0.05	0.42	0.07	0.03	0.10	0.06
Arsenic, mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.040
Barium, mg/l	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	0.002	<0.001	0.001	0.001	<0.001	<0.001	0.001	<0.001
Calcium, mg/l	28	85	19	100	31	67	30	110
Chloride, mg/l	4	5	3	5	4	4	4	6
Chromium, mg/l	<0.005	<0.005	0.005	0.020	<0.005	0.020	<0.005	<0.005
Conductivity, 25°C, umhos/cm	220	780	150	400	190	460	210	660
Copper, mg/l	0.05	0.08	0.04	0.06	0.08	0.07	0.05	0.04
Cyanide, mg/l	–	<0.01	–	–	–	–	–	–
Hardness, mg/l	86	210	62	260	96	170	95	280
Iron, mg/l	1.1	0.10	2.1	0.37	0.97	0.12	0.29	0.10
Lead, mg/l	0.052	<0.010	0.010	0.015	<0.010	<0.010	<0.010	0.010
Magnesium, mg/l	3.8	0.3	3.5	1.6	4.4	0.7	4.9	0.6
Manganese, mg/l	0.07	<0.01	0.11	0.01	0.07	0.01	0.07	0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.11	<0.01	0.10	0.03	0.17	0.02	0.16	0.02
Selenium, mg/l	<0.002	0.010	<0.002	0.008	<0.002	0.010	<0.001	0.006
Silica, mg/l	4.1	5.8	4.8	3.9	4.4	6.6	3.5	6.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	140	450	130	300	110	270	170	430
Solids, Suspended, mg/l	35	3	42	11	27	4	15	4
Sulfate, mg/l	18	260	22	140	23	120	12	160
Zinc, mg/l	0.06	0.07	0.06	0.04	0.13	0.14	0.03	0.02

Table A-9 (Continued)

TVA PLANT F RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/13/76		4/13/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.6	1.9	1.3	1.0
Ammonia as N, mg/l	0.07	0.27	0.03	0.11
Arsenic, mg/l	<0.005	<0.005	<0.005	<0.005
Barium, mg/l	<0.1	0.2	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.001	<0.001	<0.001
Calcium, mg/l	35	130	29	110
Chloride, mg/l	4	6	4	4
Chromium, mg/l	<0.005	0.058	<0.005	0.022
Conductivity, 25°C, umhos/cm	220	580	180	550
Copper, mg/l	<0.01	0.02	0.01	0.02
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	100	330	91	280
Iron, mg/l	0.73	0.31	1.6	0.24
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	3.5	0.6	4.4	1.0
Manganese, mg/l	0.06	<0.01	0.08	0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.09	0.02	0.10	<0.01
Selenium, mg/l	<0.004	<0.004	<0.002	0.005
Silica, mg/l	4.6	4.9	4.9	5.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	120	390	110	380
Solids, Suspended, mg/l	21	53	18	1
Sulfate, mg/l	17	220	13	170
Zinc, mg/l	0.02	0.06	0.16	<0.01

Table A-10

TVA PLANT G RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/4/73*		4/2/73*		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.1	NA	2.4	NA	2.9	NA	2.6
Ammonia as N, mg/l	NA	0.38	NA	0.04	NA	0.10	NA	0.01
Arsenic, mg/l	NA	0.004	NA	<0.005	NA	0.010	NA	0.070
Barium, mg/l	NA	0.4	NA	<0.1	NA	0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	0.005	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	240	NA	25	NA	110	NA	72
Chloride, mg/l	NA	8	NA	4	NA	4	NA	4
Chromium, mg/l	NA	<0.005	NA	<0.005	NA	0.023	NA	0.009
Conductivity, 25°C, umhos/cm	NA	1,000	NA	180	NA	390	NA	360
Copper, mg/l	NA	0.04	NA	0.04	NA	<0.01	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	0.02	NA	<0.01
Hardness, mg/l	NA	660	NA	81	NA	280	NA	190
Iron, mg/l	NA	72	NA	4.6	NA	0.42	NA	0.30
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	14	NA	4.6	NA	1.1	NA	1.9
Manganese, mg/l	NA	1.6	NA	0.23	NA	0.03	NA	0.02
Mercury, mg/l	NA	0.001	NA	–	NA	<0.0002	NA	–
Nickel, mg/l	NA	0.14	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.03	NA	0.03	NA	0.12	NA	0.21
Selenium, mg/l	NA	0.008	NA	–	NA	0.015	NA	<0.001
Silica, mg/l	NA	11	NA	4.9	NA	5.1	NA	5.7
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	1,100	NA	160	NA	300	NA	270
Solids, Suspended, mg/l	NA	14	NA	37	NA	8	NA	17
Sulfate, mg/l	NA	980	NA	55	NA	140	NA	88
Zinc, mg/l	NA	0.59	NA	0.02	NA	0.02	NA	0.01

NA = Not Available

*Old ash pond containing coal pile drainage only. Sampling of old pond discontinued after April 2, 1973 sample. Quarterly samples beginning July 2, 1973 are of new ash pond.

Table A-10 (Continued)

TVA PLANT G RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/14/74		4/15/74		7/15/74		10/21/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	4.1	1.4	0.8	1.7	0.4	0.5	0.1	0.4
Ammonia as N, mg/l	0.03	0.01	0.02	0.10	0.08	0.01	0.03	0.01
Arsenic, mg/l	<0.005	<0.005	<0.005	<0.030	<0.005	0.055	<0.005	0.030
Barium, mg/l	0.1	<0.1	0.1	0.1	0.1	0.2	<0.1	0.3
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium, mg/l	21	78	17	80	18	73	24	110
Chloride, mg/l	3	3	5	8	3	3	4	2
Chromium, mg/l	-	0.010	0.010	0.023	<0.005	0.010	<0.005	0.006
Conductivity, 25°C, umhos/cm	140	320	140	420	150	420	190	460
Copper, mg/l	0.16	<0.01	0.08	0.06	<0.01	0.09	0.02	<0.01
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	69	210	60	210	61	190	78	280
Iron, mg/l	4.6	0.26	0.99	0.41	0.54	0.40	0.55	0.27
Lead, mg/l	0.04	<0.010	0.016	<0.010	0.020	0.022	<0.010	<0.010
Magnesium, mg/l	4.0	2.7	4.3	2.9	4.0	2.1	4.4	2.3
Manganese, mg/l	0.23	<0.01	0.05	<0.01	0.07	0.01	0.08	0.03
Mercury, mg/l	<0.0002	0.014	<0.0002	<0.0002	0.0031	0.0026	0.0013	<0.002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.12	0.05	0.08	0.05	0.03	-	0.07	0.09
Selenium, mg/l	0.004	0.018	<0.002	0.008	<0.002	0.006	<0.002	0.010
Silica, mg/l	5.0	4.2	5.4	5.1	-	-	4.6	3.9
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	270	90	290	90	310	110	320
Solids, Suspended, mg/l	67	13	20	20	5	14	6	8
Sulfate, mg/l	13	120	18	180	20	190	18	160
Zinc, mg/l	0.08	<0.01	0.11	0.06	0.03	0.03	0.10	0.07

Table A-10 (Continued)

TVA PLANT G RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/13/75		4/9/75		7/14/75		10/8/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.7	1.3	2.8	1.9	0.8	1.8	<0.2	1.3
Ammonia as N, mg/l	0.01	0.04	0.02	0.08	0.06	<0.01	0.06	0.62
Arsenic, mg/l	<0.005	0.025	<0.005	0.016	<0.005	0.040	0.005	0.075
Barium, mg/l	<0.1	0.2	0.1	0.2	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001
Calcium, mg/l	25	47	13	38	19	48	24	75
Chloride, mg/l	4	3	3	3	3	4	3	4
Chromium, mg/l	<0.005	0.020	<0.005	0.009	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	190	330	120	320	150	290	150	380
Copper, mg/l	0.02	0.02	0.07	0.06	0.08	0.11	0.10	0.12
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	81	130	46	110	62	130	76	200
Iron, mg/l	0.91	0.61	2.3	0.72	0.33	1.4	0.45	0.52
Lead, mg/l	0.036	0.036	0.011	0.013	<0.010	<0.010	0.010	<0.010
Magnesium, mg/l	4.6	3.1	3.4	2.5	3.5	2.3	3.8	3.1
Manganese, mg/l	0.09	0.04	0.09	0.02	0.08	0.04	0.08	0.02
Mercury, mg/l	<0.0002	<0.0002	0.0320	0.0037	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.07	0.10	0.09	0.07	0.08	0.14	0.16	0.09
Selenium, mg/l	<0.002	<0.002	<0.002	0.013	<0.002	0.006	<0.001	0.019
Silica, mg/l	4.8	3.4	3.5	4.9	4.0	7.1	3.5	4.3
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	110	220	70	200	480	190	100	290
Solids, Suspended, mg/l	19	18	14	45	6	24	5	27
Sulfate, mg/l	17	100	23	130	22	96	<1	620
Zinc, mg/l	0.05	0.08	0.13	0.10	0.11	0.10	0.08	0.05

Table A-10 (Continued)

TVA PLANT G RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/7/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.7	2.0	1.1	1.4
Ammonia as N, mg/l	0.02	0.12	0.02	0.02
Arsenic, mg/l	<0.005	0.070	<0.005	0.078
Barium, mg/l	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001
Calcium, mg/l	28	100	24	42
Chloride, mg/l	5	4	4	4
Chromium, mg/l	<0.005	0.020	<0.005	<0.005
Conductivity, 25°C, umhos/cm	160	370	160	270
Copper, mg/l	0.02	0.01	0.01	0.02
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	88	260	77	120
Iron, mg/l	0.78	0.08	1.5	0.56
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	4.5	3.4	4.2	2.6
Manganese, mg/l	0.07	0.03	0.10	0.02
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0006
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.12	0.08	0.07	0.06
Selenium, mg/l	<0.002	0.016	<0.002	0.046
Silica, mg/l	4.5	4.2	4.8	5.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	110	270	90	160
Solids, Suspended, mg/l	9	41	13	17
Sulfate, mg/l	18	120	21	82
Zinc, mg/l	<0.01	0.01	<0.01	0.04

Table A-11

TVA PLANT H RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/2/73		4/2/73		7/2/73		10/2/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.2	NA	2.9	NA	1.9	NA	2.5
Ammonia as N, mg/l	NA	0.48	NA	0.16	NA	0.03	NA	0.06
Arsenic, mg/l	NA	0.076	NA	0.070	NA	0.180	NA	0.140
Barium, mg/l	NA	0.1	NA	0.2	NA	0.1	NA	0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	39	NA	46	NA	49	NA	67
Chloride, mg/l	NA	12	NA	15	NA	20	NA	22
Chromium, mg/l	NA	<0.005	NA	<0.005	NA	<0.005	NA	0.008
Conductivity, 25°C, umhos/cm	NA	330	NA	350	NA	380	NA	460
Copper, mg/l	NA	<0.01	NA	0.05	NA	<0.01	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	130	NA	150	NA	150	NA	200
Iron, mg/l	NA	0.48	NA	1.4	NA	0.24	NA	0.51
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	8.1	NA	7.8	NA	7.6	NA	8.8
Manganese, mg/l	NA	0.07	NA	0.07	NA	0.02	NA	0.03
Mercury, mg/l	NA	0.0007	NA	0.0016	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.40	NA	0.21	NA	0.62	NA	0.63
Selenium, mg/l	NA	<0.004	NA	–	NA	0.014	NA	0.024
Silica, mg/l	NA	5.6	NA	5.2	NA	2.7	NA	3.6
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	200	NA	240	NA	240	NA	300
Solids, Suspended, mg/l	NA	5	NA	19	NA	8	NA	7
Sulfate, mg/l	NA	85	NA	45	NA	65	NA	120
Zinc, mg/l	NA	0.01	NA	<0.01	NA	0.01	NA	0.02

NA = Not Available

Table A-11 (Continued)

TVA PLANT H RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/14/74		4/9/74		7/15/74		12/4/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.2	1.4	1.1	1.1	0.6	1.2	<0.2	0.8
Ammonia as N, mg/l	0.11	0.16	0.24	0.03	0.06	0.04	0.15	2.6
Arsenic, mg/l	0.01	0.055	<0.005	0.035	<0.005	0.140	<0.005	0.065
Barium, mg/l	<0.1	<0.1	0.2	0.3	0.2	0.3	0.2	0.3
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Calcium, mg/l	29	42	26	42	23	60	22	34
Chloride, mg/l	7	8	9	10	9	10	10	16
Chromium, mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	0.010
Conductivity, 25°C, umhos/cm	220	350	230	350	220	440	240	400
Copper, mg/l	0.15	<0.01	0.05	0.10	0.03	0.04	0.11	0.14
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	100	130	88	130	82	180	82	120
Iron, mg/l	1.4	0.88	0.99	0.70	0.59	0.22	0.45	0.64
Lead, mg/l	0.040	0.030	<0.010	<0.010	0.016	0.010	<0.010	<0.010
Magnesium, mg/l	7.3	6.2	5.7	5.8	5.9	6.8	6.5	7.8
Manganese, mg/l	0.14	0.07	0.10	0.04	0.11	0.02	0.10	0.08
Mercury, mg/l	0.0008	0.0002	<0.0002	<0.0002	<0.0002	0.0012	0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
Phosphorous, mg/l	0.06	0.06	0.06	0.04	0.06	0.13	0.06	0.14
Selenium, mg/l	0.006	0.014	<0.002	0.004	<0.002	<0.002	<0.002	0.028
Silica, mg/l	6.0	5.3	6.6	5.5	2.7	-	5.9	5.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	120	200	130	210	110	290	130	220
Solids, Suspended, mg/l	27	19	29	18	22	5	10	4
Sulfate, mg/l	18	100	17	80	16	140	20	70
Zinc, mg/l	0.08	0.01	0.06	0.07	0.05	0.05	0.10	0.15

Table A-11 (Continued)

TVA PLANT H RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/14/75		4/8/75		7/9/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.8	1.2	1.6	1.7	1.3	1.6	0.9	1.3
Ammonia as N, mg/l	0.42	0.23	0.12	0.03	0.49	0.18	0.24	0.06
Arsenic, mg/l	<0.005	0.060	<0.005	0.240	<0.005	0.100	0.010	0.360
Barium, mg/l	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.001	0.001	0.002	<0.001	<0.001	<0.001	0.002
Calcium, mg/l	32	49	22	40	34	67	35	65
Chloride, mg/l	17	13	6	9	28	15	24	22
Chromium, mg/l	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	280	400	240	420	310	490	330	510
Copper, mg/l	0.02	0.01	0.08	0.04	0.07	0.02	0.08	0.09
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	110	150	80	130	120	200	140	200
Iron, mg/l	1.5	0.65	1.7	0.44	0.83	0.33	0.92	0.18
Lead, mg/l	0.020	0.036	0.033	0.021	<0.010	<0.010	0.012	<0.010
Magnesium, mg/l	6.4	7.0	6.2	6.6	8.1	6.8	13	9.7
Manganese, mg/l	0.17	0.10	0.12	0.06	0.17	0.07	0.18	0.03
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.45	0.09	0.08	0.06	0.18	0.12	0.14	0.16
Selenium, mg/l	<0.002	0.020	<0.002	0.034	<0.002	0.020	<0.001	0.023
Silica, mg/l	5.8	5.5	4.6	5.3	4.4	4.6	3.3	4.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	170	230	140	270	180	320	180	350
Solids, Suspended, mg/l	29	15	26	6	24	5	22	7
Sulfate, mg/l	19	90	18	150	21	130	22	100
Zinc, mg/l	0.11	0.04	0.07	0.06	0.04	0.04	0.33	0.08

Table A-12

TVA PLANT H RIVER WATER INTAKE AND FLY ASH POND DISCHARGE DA
(Quarterly Samples)

Date	1/14/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Dischar
Aluminum, mg/l	NA	2.2	NA	2.2
Ammonia as N, mg/l	NA	0.19	NA	0.1
Arsenic, mg/l	NA	0.085	NA	0.2
Barium, mg/l	NA	<0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.0
Cadmium, mg/l	NA	0.007	NA	0.0
Calcium, mg/l	NA	69	NA	91
Chloride, mg/l	NA	11	NA	20
Chromium, mg/l	NA	0.011	NA	0.01
Conductivity, 25°C, umhos/cm	NA	440	NA	630
Copper, mg/l	NA	0.02	NA	0.16
Cyanide, mg/l	NA	-	NA	-
Hardness, mg/l	NA	200	NA	280
Iron, mg/l	NA	0.80	NA	2.3
Lead, mg/l	NA	<0.010	NA	<0.01
Magnesium, mg/l	NA	7.4	NA	12
Manganese, mg/l	NA	0.08	NA	0.19
Mercury, mg/l	NA	<0.0002	NA	0.00
Nickel, mg/l	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.09	NA	0.0
Selenium, mg/l	NA	0.019	NA	-
Silica, mg/l	NA	5.9	NA	4.9
Silver, mg/l	NA	<0.01	NA	<0.0
Solids, Dissolved, mg/l	NA	290	NA	450
Solids, Suspended, mg/l	NA	35	NA	11
Sulfate, mg/l	NA	140	NA	220
Zinc, mg/l	NA	0.10	NA	0.

Table A-13

TVA PLANT H RIVER WATER INTAKE AND BOTTOM ASH POND DISCHARGE DATA
(Quarterly Samples)

Date	1/14/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	*	1.7	0.5	0.9
Ammonia as N, mg/l	0.27	0.15	0.55	0.18
Arsenic, mg/l	<0.005	0.060	<0.010	NES
Barium, mg/l	*	<0.1	<0.1	0.4
Beryllium, mg/l	*	<0.01	<0.01	<0.01
Cadmium, mg/l	*	0.001	<0.001	<0.001
Calcium, mg/l	*	49	43	55
Chloride, mg/l	11	11	27	21
Chromium, mg/l	*	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	260	340	390	420
Copper, mg/l	*	<0.01	0.03	<0.01
Cyanide, mg/l	–	–	–	–
Hardness, mg/l	*	150	150	180
Iron, mg/l	*	1.2	0.53	0.72
Lead, mg/l	*	<0.010	0.013	<0.010
Magnesium, mg/l	*	6.1	9.3	11
Manganese, mg/l	*	0.04	0.14	0.06
Mercury, mg/l	*	<0.0002	<0.0002	<0.0002
Nickel, mg/l	*	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.09	0.12	0.24	0.10
Selenium, mg/l	<0.002	0.010	<0.002	*
Silica, mg/l	6.5	5.5	2.3	3.8
Silver, mg/l	*	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	150	210	200	260
Solids, Suspended, mg/l	23	35	4	2
Sulfate, mg/l	20	59	42	100
Zinc, mg/l	*	<0.01	0.02	<0.01

*Bottle Received Broken.

Table A-14

TVA PLANT I RIVER WATER INTAKE AND COMBINED ASH POND (SOUTH) DISCHARGE
(Quarterly Samples)

Date	1/3/73		5/16/73		7/9/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	0.6	NA	1.2	NA	1.6	NA	1.1
Ammonia as N, mg/l	NA	0.31	NA	0.05	NA	0.05	NA	0.03
Arsenic, mg/l	NA	<0.005	NA	–	NA	0.005	NA	0.005
Barium, mg/l	NA	0.1	NA	0.2	NA	0.1	NA	0.2
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	–	NA	<0.001
Calcium, mg/l	NA	110	NA	99	NA	140	NA	100
Chloride, mg/l	NA	11	NA	6	NA	6	NA	7
Chromium, mg/l	NA	0.016	NA	0.006	NA	0.021	NA	0.026
Conductivity, 25°C, umhos/cm	NA	610	NA	540	NA	750	NA	680
Copper, mg/l	NA	<0.01	NA	0.02	NA	0.02	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	280	NA	250	NA	350	NA	250
Iron, mg/l	NA	0.05	NA	0.09	NA	0.09	NA	<0.05
Lead, mg/l	NA	<0.010	NA	<0.010	NA	–	NA	0.010
Magnesium, mg/l	NA	0.4	NA	0.2	NA	0.4	NA	0.2
Manganese, mg/l	NA	<0.01	NA	0.01	NA	<0.01	NA	<0.01
Mercury, mg/l	NA	0.0012	NA	<0.0002	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	0.05
Phosphorous, mg/l	NA	0.05	NA	0.03	NA	0.06	NA	<0.03
Selenium, mg/l	NA	<0.004	NA	0.004	NA	0.004	NA	0.006
Silica, mg/l	NA	7.1	NA	7.4	NA	7.0	NA	7.6
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	280	NA	230	NA	300	NA	300
Solids, Suspended, mg/l	NA	3	NA	2	NA	6	NA	3
Sulfate, mg/l	NA	60	NA	50	NA	75	NA	64
Zinc, mg/l	NA	<0.01	NA	0.24	NA	0.01	NA	0.03

NA = Not Available

Table A-14 (Continued)

TVA PLANT I RIVER WATER INTAKE AND COMBINED ASH POND (SOUTH) DISCHARGE
(Quarterly Samples)

Date	2/19/74		4/8/74		7/15/74		10/15/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.4	0.8	2.0	1.1	0.8	2.0	1.2	2.6
Ammonia as N, mg/l	0.05	0.03	0.08	0.06	0.02	0.03	0.04	0.03
Arsenic, mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Barium, mg/l	0.2	0.3	0.3	0.2	0.1	0.2	<0.1	0.5
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001
Calcium, mg/l	21	74	20	46	18	92	21	140
Chloride, mg/l	4	4	4	4	6	5	8	10
Chromium, mg/l	<0.005	0.030	<0.005	4	<0.005	0.020	<0.005	0.026
Conductivity, 25°C, umhos/cm	170	540	150	440	150	750	180	940
Copper, mg/l	0.11	0.13	0.10	0.05	0.07	0.15	0.12	0.10
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	66	190	64	120	59	230	70	350
Iron, mg/l	1.7	0.15	1.8	0.28	0.80	0.25	0.61	0.17
Lead, mg/l	0.021	<0.010	0.014	<0.010	0.017	0.038	0.016	0.010
Magnesium, mg/l	3.3	0.4	3.3	0.5	3.5	0.3	4.3	0.2
Manganese, mg/l	0.11	<0.01	0.12	0.5	0.06	<0.01	0.01	0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.15	0.01	0.21	0.04	0.04	<0.01	0.10	<0.01
Selenium, mg/l	0.002	0.08	<0.002	0.007	<0.002	<0.002	<0.002	0.012
Silica, mg/l	5.6	7.9	5.9	7.8	3.2	-	-	9.1
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	220	90	190	90	230	100	370
Solids, Suspended, mg/l	18	4	28	2	16	<1	3	2
Sulfate, mg/l	12	61	14	58	10	90	12	100
Zinc, mg/l	0.08	0.07	0.12	0.08	0.09	0.09	0.05	0.08

Table A-14 (Continued)

TVA PLANT I RIVER WATER INTAKE AND COMBINED ASH POND (SOUTH) DISCHARGE
(Quarterly Samples)

Date	1/13/75		4/7/75		7/14/75		10/20/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	3.0	1.4	2.0	1.9	*	2.1	1.0	1.2
Ammonia as N, mg/l	0.10	0.06	0.04	0.10	0.03	0.01	0.07	0.07
Arsenic, mg/l	<0.005	0.010	<0.005	0.100	*	0.110	<0.005	0.160
Barium, mg/l	<0.1	<0.1	0.3	<0.1	*	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	*	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	0.001	0.001	*	<0.001	<0.001	<0.001
Calcium, mg/l	18	44	17	45	*	58	19	61
Chloride, mg/l	5	6	6	4	5	4	6	7
Chromium, mg/l	<0.005	0.024	0.005	0.007	*	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	130	310	140	310	150	330	150	350
Copper, mg/l	0.01	0.02	0.06	0.02	*	0.09	0.04	0.04
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	56	120	53	120	*	160	61	180
Iron, mg/l	3.9	0.35	1.8	0.58	*	0.47	1.5	0.57
Lead, mg/l	0.014	0.012	0.012	0.019	*	<0.010	<0.010	<0.010
Magnesium, mg/l	2.7	2.0	2.6	2.2	*	3.7	3.4	3.5
Manganese, mg/l	0.20	0.02	0.12	0.01	*	0.02	0.11	<0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0005	<0.0002	<0.0002	0.0003	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	*	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.36	0.05	0.15	0.09	0.10	0.25	0.26	0.24
Selenium, mg/l	<0.002	<0.002	<0.002	0.007	<0.002	0.008	<0.001	0.005
Silica, mg/l	6.4	6.3	6.5	6.0	4.4	6.0	5.9	6.2
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	*	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	190	100	210	90	220	90	230
Solids, Suspended, mg/l	57	15	16	7	20	4	31	15
Sulfate, mg/l	10	50	20	70	11	200	12	88
Zinc, mg/l	0.05	0.04	0.11	0.06	*	0.11	0.03	0.10

*Bottle Broken

Table A-14 (Continued)

TVA PLANT I RIVER WATER INTAKE AND COMBINED ASH POND (SOUTH) DISCHARGE (Quarterly Samples)

Date	1/12/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.1	3.4	1.0	0.4
Ammonia as N, mg/l	0.07	0.20	0.05	0.07
Arsenic, mg/l	<0.005	0.035	<0.005	0.010
Barium, mg/l	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.010
Calcium, mg/l	27	59	26	140
Chloride, mg/l	7	6	5	6
Chromium, mg/l	<0.005	0.012	<0.005	0.006
Conductivity, 25°C, umhos/cm	150	310	170	880
Copper, mg/l	<0.01	<0.01	0.03	<0.01
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	81	160	79	350
Iron, mg/l	1.0	1.0	1.2	0.07
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	3.2	3.6	3.4	0.5
Manganese, mg/l	0.07	0.01	0.09	0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.11	0.24	0.11	0.03
Selenium, mg/l	<0.002	0.015	<0.002	0.020
Silica, mg/l	6.3	6.1	5.0	8.1
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	110	200	90	360
Solids, Suspended, mg/l	9	48	10	15
Sulfate, mg/l	12	59	12	120
Zinc, mg/l	0.02	<0.01	0.02	0.06

Table A-15

TVA PLANT J RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/3/73		4/3/73		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	3.6	NA	5.0	NA	0.4	NA	1.3
Ammonia as N, mg/l	NA	0.08	NA	0.04	NA	0.06	NA	0.04
Arsenic, mg/l	NA	0.018	NA	0.014	NA	0.015	NA	0.080
Barium, mg/l	NA	0.1	NA	<0.1	NA	<0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	0.002	NA	0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	30	NA	31	NA	39	NA	57
Chloride, mg/l	NA	3	NA	3	NA	4	NA	4
Chromium, mg/l	NA	0.006	NA	<0.005	NA	<0.005	NA	0.005
Conductivity, 25°C, umhos/cm	NA	360	NA	340	NA	320	NA	380
Copper, mg/l	NA	0.05	NA	0.03	NA	0.02	NA	0.02
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	96	NA	100	NA	130	NA	180
Iron, mg/l	NA	2.7	NA	3.4	NA	0.66	NA	0.58
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	5.0	NA	6.0	NA	8.2	NA	9.3
Manganese, mg/l	NA	0.66	NA	0.62	NA	0.44	NA	0.16
Mercury, mg/l	NA	0.0008	NA	<0.0002	NA	<0.0002	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.5	NA	<0.05
Phosphorous, mg/l	NA	0.15	NA	0.03	NA	0.04	NA	0.39
Selenium, mg/l	NA	<0.004	NA	0.003	NA	0.002	NA	<0.001
Silica, mg/l	NA	7.5	NA	7.9	NA	5.7	NA	5.6
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	210	NA	220	NA	200	NA	250
Solids, Suspended, mg/l	NA	2	NA	35	NA	2	NA	5
Sulfate, mg/l	NA	140	NA	120	NA	120	NA	120
Zinc, mg/l	NA	0.04	NA	0.06	NA	0.04	NA	0.02

NA = Not Available

Table A-15 (Continued)

TVA PLANT J RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/14/74		4/4/74		7/15/74		10/8/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.9	7.6	1.4	2.1	0.4	1.0	0.3	0.4
Ammonia as N, mg/l	<0.01	0.05	0.02	<0.08	0.01	<0.01	0.01	0.01
Arsenic, mg/l	<0.005	0.025	<0.005	<0.005	0.110	0.110	<0.005	0.040
Barium, mg/l	<0.1	<0.1	0.4	0.3	0.2	0.2	0.2	0.2
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.001	<0.001
Calcium, mg/l	5	32	4	23	26	38	30	47
Chloride, mg/l	2	2	2	3	3	2	4	3
Chromium, mg/l	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	0.006	0.006
Conductivity, 25°C, umhos/cm	44	370	51	250	320	320	240	350
Copper, mg/l	0.13	0.08	0.12	0.18	0.04	0.05	0.04	0.04
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	19	100	16	73	95	130	110	150
Iron, mg/l	0.91	9.4	1.5	1.2	0.44	0.39	0.26	0.10
Lead, mg/l	<0.01	0.028	0.020	<0.010	<0.010	0.038	<0.010	<0.010
Magnesium, mg/l	1.6	5.7	1.5	3.9	7.3	8.2	8.3	8.6
Manganese, mg/l	0.08	0.68	0.07	0.40	0.03	0.05	0.03	0.08
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0005	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	<0.01	0.03	0.03	0.04	0.02	0.11	0.02	0.03
Selenium, mg/l	<0.002	0.006	<0.002	<0.002	0.008	0.004	<0.002	<0.002
Silica, mg/l	4.1	6.8	4.5	6.5	1.0	-	4.0	3.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	40	250	40	140	210	200	130	220
Solids, Suspended, mg/l	10	81	35	12	7	9	5	1
Sulfate, mg/l	13	170	13	120	80	90	14	94
Zinc, mg/l	0.08	0.09	0.09	0.12	0.08	0.03	0.05	0.03

Table A-15 (Continued)

TVA PLANT J RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/15/75		4/8/75		7/14/75		10/15/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.6	4.4	1.0	3.0	1.0	1.5	0.3	1.4
Ammonia as N, mg/l	0.02	0.04	0.23	3.7	0.02	0.07	0.03	0.03
Arsenic, mg/l	<0.005	0.005	<0.005	<0.005	0.007	0.130	<0.005	0.040
Barium, mg/l	<0.1	0.2	<0.1	0.3	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.001	<0.001
Calcium, mg/l	4.0	29	8.0	20	24	40	20	25
Chloride, mg/l	2	2	4	21	3	6	3	3
Chromium, mg/l	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	44	390	90	420	200	310	160	230
Copper, mg/l	<0.01	0.04	0.06	0.73	0.11	0.05	0.09	0.05
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	15	94	30	67	89	140	76	85
Iron, mg/l	0.50	5.2	0.61	3.8	1.1	0.86	0.28	0.52
Lead, mg/l	0.18	0.014	0.011	0.018	<0.010	<0.010	0.010	<0.010
Magnesium, mg/l	1.2	5.3	2.4	4.1	7.1	9.9	6.4	5.6
Manganese, mg/l	0.06	0.79	0.18	0.40	0.05	0.14	0.06	0.13
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	<0.0002	0.0009	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	0.08	<0.05	0.05	<0.05	<0.05
Phosphorous, mg/l	0.01	<0.01	0.01	0.08	0.02	0.11	0.03	0.07
Selenium, mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	0.008	<0.001	0.007
Silica, mg/l	3.9	6.6	4.8	8.7	5.0	7.1	3.8	4.7
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	30	210	50	170	110	200	100	150
Solids, Suspended, mg/l	5	9	25	9	7	4	7	6
Sulfate, mg/l	9	180	14	140	16	72	13	56
Zinc, mg/l	0.04	0.11	0.04	0.25	0.03	0.02	0.04	0.08

Table A-15 (Continued)

TVA PLANT J RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/7/76		4/13/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	0.4	1.5	0.6	1.3
Ammonia as N, mg/l	0.01	0.04	0.01	0.07
Arsenic, mg/l	<0.005	0.090	<0.010	0.100
Barium, mg/l	<0.1	0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.002	<0.001	0.0001
Calcium, mg/l	6.0	23	9.0	22
Chloride, mg/l	3	3	3	3
Chromium, mg/l	0.014	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	48	230	74	NES
Copper, mg/l	0.01	0.03	0.05	0.09
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	20	70	32	68
Iron, mg/l	0.45	3.2	0.84	1.5
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	1.3	3.0	2.2	3.2
Manganese, mg/l	0.07	0.28	0.11	0.32
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0006
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.01	0.09	0.02	0.03
Selenium, mg/l	<0.002	0.004	<0.002	0.004
Silica, mg/l	4.1	5.6	4.6	6.2
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	40	70	50	140
Solids, Suspended, mg/l	4	14	6	4
Sulfate, mg/l	10	85	18	92
Zinc, mg/l	<0.01	0.04	<0.01	0.06

Table A-16

TVA PLANT K RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/2/73		4/2/73		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	1.3	NA	1.9	NA	2.3	NA	0.5
Ammonia as N, mg/l	NA	0.05	NA	0.03	NA	0.16	NA	0.02
Arsenic, mg/l	NA	0.008	NA	<0.005	NA	-	NA	0.025
Barium, mg/l	NA	<0.1	NA	<0.1	NA	0.2	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	87	NA	110	NA	130	NA	75
Chloride, mg/l	NA	13	NA	9	NA	13	NA	19
Chromium, mg/l	NA	0.022	NA	0.015	NA	0.023	NA	0.023
Conductivity, 25°C, umhos/cm	NA	380	NA	520	NA	580	NA	480
Copper, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	0.03
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	220	NA	280	NA	330	NA	190
Iron, mg/l	NA	0.11	NA	0.34	NA	0.17	NA	0.13
Lead, mg/l	NA	<0.010	NA	<0.010	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	1.0	NA	0.4	NA	0.7	NA	1.1
Manganese, mg/l	NA	<0.01	NA	0.02	NA	<0.01	NA	<0.01
Mercury, mg/l	NA	0.0008	NA	0.0003	NA	0.0008	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	0.22
Phosphorous, mg/l	NA	0.03	NA	<0.03	NA	0.06	NA	0.10
Selenium, mg/l	NA	0.016	NA	0.008	NA	0.008	NA	0.012
Silica, mg/l	NA	7.0	NA	7.4	NA	8.8	NA	7.1
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	220	NA	240	NA	290	NA	310
Solids, Suspended, mg/l	NA	7	NA	5	NA	3	NA	6
Sulfate, mg/l	NA	72	NA	55	NA	90	NA	88
Zinc, mg/l	NA	0.11	NA	<0.01	NA	0.02	NA	0.02

NA = Not Available

Table A-16 (Continued)

TVA PLANT K RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/14/74		4/8/74		7/15/74		10/8/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	2.8	1.8	2.3	1.8	3.4	2.4	1.4	1.3
Ammonia as N, mg/l	0.08	0.06	0.04	0.03	0.06	0.04	0.24	0.07
Arsenic, mg/l	0.015	0.010	<0.005	0.005	<0.005	<0.005	<0.005	0.025
Barium, mg/l	<0.1	<0.1	0.3	0.3	0.2	0.2	0.1	0.3
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	0.001	<0.001	<0.001	0.001	0.002	<0.001	<0.001
Calcium, mg/l	15	77	16	52	18	76	28	92
Chloride, mg/l	6	11	6	9	6	7	10	12
Chromium, mg/l	0.027	0.014	0.012	0.019	<0.005	0.026	0.006	0.026
Conductivity, 25°C, umhos/cm	140	500	160	460	150	640	260	400
Copper, mg/l	0.12	0.07	0.12	0.08	<0.01	0.10	0.04	0.05
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	52	190	56	130	61	190	98	240
Iron, mg/l	2.6	0.32	2.2	0.33	3.3	0.33	1.3	0.18
Lead, mg/l	0.022	0.017	<0.010	<0.010	0.030	0.040	<0.010	0.014
Magnesium, mg/l	3.6	0.6	3.8	0.6	3.8	0.5	6.9	3.0
Manganese, mg/l	0.09	<0.01	0.11	<0.01	0.18	<0.01	0.07	<0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.13	0.01	0.10	0.01	0.06	<0.01	0.08	0.06
Selenium, mg/l	<0.002	0.014	<0.002	0.012	<0.002	<0.002	<0.002	0.012
Silica, mg/l	5.3	6.5	4.8	8.0	2.5	-	5.9	6.7
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	90	240	100	220	80	250	150	240
Solids, Suspended, mg/l	31	10	26	8	60	3	30	5
Sulfate, mg/l	22	89	18	100	13	90	31	110
Zinc, mg/l	0.09	0.08	0.08	0.06	0.04	0.04	0.06	0.05

Table A-16 (Continued)

TVA PLANT K RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/13/75		4/7/75		7/14/75		10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.8	3.1	2.6	1.7	1.1	2.2	0.6	1.4
Ammonia as N, mg/l	0.05	0.08	0.13	0.10	0.06	0.04	0.05	0.02
Arsenic, mg/l	<0.005	0.045	<0.005	0.050	0.024	0.100	<0.005	0.085
Barium, mg/l	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001
Calcium, mg/l	21	60	12	47	25	64	22	44
Chloride, mg/l	6	8	4	7	8	6	8	9
Chromium, mg/l	<0.005	0.036	0.009	0.009	<0.005	0.015	<0.005	<0.005
Conductivity, 25°C, umhos/cm	160	350	120	320	200	340	150	300
Copper, mg/l	0.02	0.02	0.08	0.03	0.11	0.01	0.09	0.09
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	66	160	40	130	87	180	73	120
Iron, mg/l	1.8	1.0	2.2	0.37	1.4	1.2	0.66	0.18
Lead, mg/l	0.020	0.048	0.010	0.012	<0.010	<0.010	<0.010	0.010
Magnesium, mg/l	3.4	2.4	2.5	2.4	6.0	3.6	4.4	3.0
Manganese, mg/l	0.10	0.03	0.07	0.01	0.10	0.04	0.08	0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.11	0.06	0.11	0.08	0.09	0.17	0.09	0.12
Selenium, mg/l	<0.002	<0.002	<0.002	0.011	<0.002	0.009	<0.001	0.008
Silica, mg/l	5.6	6.6	5.0	4.0	2.5	5.3	5.4	5.8
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	210	110	240	120	240	100	180
Solids, Suspended, mg/l	20	26	21	7	23	6	17	11
Sulfate, mg/l	12	60	19	88	23	100	21	54
Zinc, mg/l	0.04	0.04	0.06	0.02	0.11	0.07	0.06	0.04

Table A-16 (Continued)

TVA PLANT K RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/12/76		4/12/76	
	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.2	1.4	1.0	0.7
Ammonia as N, mg/l	0.05	0.11	0.04	1.3
Arsenic, mg/l	<0.005	0.060	<0.010	0.092
Barium, mg/l	<0.1	<0.1	<0.1	0.3
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001
Calcium, mg/l	23	59	30	69
Chloride, mg/l	7	8	8	19
Chromium, mg/l	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	150	320	210	370
Copper, mg/l	<0.01	<0.01	0.03	0.04
Cyanide, mg/l	-	-	-	-
Hardness, mg/l	71	160	96	180
Iron, mg/l	1.2	0.26	1.7	0.20
Lead, mg/l	<0.010	<0.010	<0.010	<0.010
Magnesium, mg/l	3.4	3.0	5.0	3.0
Manganese, mg/l	0.07	<0.01	0.14	0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.10	0.06	0.13	0.02
Selenium, mg/l	0.009	0.012	<0.002	0.003
Silica, mg/l	5.9	5.9	4.8	5.6
Silver, mg/l	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	100	200	110	200
Solids, Suspended, mg/l	22	4	24	4
Sulfate, mg/l	16	59	24	91
Zinc, mg/l	<0.01	<0.01	0.04	0.03

Table A-17

TVA PLANT L RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/8/73		4/2/73		7/2/73		10/1/73	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	NA	2.1	NA	2.2	NA	2.6	NA	1.8
Ammonia as N, mg/l	NA	0.37	NA	1.3	NA	0.20	NA	1.4
Arsenic, mg/l	NA	0.036	NA	0.030	NA	0.070	NA	0.070
Barium, mg/l	NA	<0.1	NA	0.1	NA	<0.1	NA	<0.1
Beryllium, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Cadmium, mg/l	NA	<0.001	NA	<0.001	NA	<0.001	NA	<0.001
Calcium, mg/l	NA	44	NA	38	NA	91	NA	53
Chloride, mg/l	NA	6	NA	4	NA	6	NA	9
Chromium, mg/l	NA	0.009	NA	0.007	NA	<0.005	NA	0.009
Conductivity, 25°C, umhos/cm	NA	120	NA	270	NA	330	NA	360
Copper, mg/l	NA	<0.01	NA	<0.01	NA	0.01	NA	<0.01
Cyanide, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Hardness, mg/l	NA	130	NA	110	NA	240	NA	150
Iron, mg/l	NA	0.90	NA	1.0	NA	0.54	NA	0.58
Lead, mg/l	NA	<0.010	NA	0.043	NA	<0.010	NA	<0.010
Magnesium, mg/l	NA	3.9	NA	4.0	NA	4.2	NA	3.5
Manganese, mg/l	NA	<0.01	NA	0.06	NA	<0.01	NA	<0.01
Mercury, mg/l	NA	0.0009	NA	0.0005	NA	–	NA	<0.0002
Nickel, mg/l	NA	<0.05	NA	<0.05	NA	<0.05	NA	<0.05
Phosphorous, mg/l	NA	0.19	NA	0.03	NA	0.45	NA	0.42
Selenium, mg/l	NA	<0.004	NA	0.013	NA	0.013	NA	0.014
Silica, mg/l	NA	5.6	NA	5.0	NA	5.9	NA	5.4
Silver, mg/l	NA	<0.01	NA	<0.01	NA	<0.01	NA	<0.01
Solids, Dissolved, mg/l	NA	230	NA	190	NA	240	NA	230
Solids, Suspended, mg/l	NA	11	NA	8	NA	3	NA	5
Sulfate, mg/l	NA	100	NA	60	NA	75	NA	110
Zinc, mg/l	NA	0.04	NA	0.02	NA	0.03	NA	0.02

NA = Not Available

Table A-17 (Continued)

TVA PLANT L RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/15/74		4/9/74		7/16/74		10/22/74	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	2.8	2.0	2.3	2.5	0.7	2.2	0.3	1.3
Ammonia as N, mg/l	0.04	0.60	0.05	0.46	0.07	0.06	0.08	0.73
Arsenic, mg/l	<0.005	0.045	<0.005	0.010	<0.005	0.015	0.010	0.010
Barium, mg/l	0.1	<0.1	0.2	0.2	0.2	0.2	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001
Calcium, mg/l	14	60	17	72	17	47	17	32
Chloride, mg/l	4	4	4	4	6	6	8	8
Chromium, mg/l	0.021	0.005	<0.005	0.010	<0.005	0.010	0.010	0.012
Conductivity, 25°C, umhos/cm	110	300	130	560	170	310	180	270
Copper, mg/l	0.14	0.07	0.10	0.08	0.04	0.14	<0.01	<0.01
Cyanide, mg/l	-	<0.01	-	<0.01	-	<0.01	-	-
Hardness, mg/l	50	160	56	190	60	130	61	92
Iron, mg/l	2.40	0.87	1.9	0.85	0.61	0.38	0.28	0.41
Lead, mg/l	0.02	<0.010	0.012	<0.010	0.014	0.036	<0.010	<0.010
Magnesium, mg/l	3.7	2.0	3.4	1.3	4.3	2.6	4.4	3.0
Manganese, mg/l	0.12	<0.01	0.08	0.01	0.05	<0.01	0.03	<0.01
Mercury, mg/l	0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.01	0.01	0.06	0.02	0.02	0.08	0.04	0.05
Selenium, mg/l	<0.002	0.014	<0.002	0.008	<0.002	<0.002	<0.002	<0.002
Silica, mg/l	5.2	5.2	5.4	6.7	3.6	-	5.1	5.3
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Solids, Dissolved, mg/l	80	220	80	230	90	230	100	150
Solids, Suspended, mg/l	30	27	43	50	8	9	4	4
Sulfate, mg/l	11	80	15	90	14	110	14	55
Zinc, mg/l	0.08	0.02	0.07	0.06	0.04	0.05	0.05	0.05

Table A-17 (Continued)

TVA PLANT L RIVER WATER INTAKE AND COMBINED ASH POND DISCHARGE
(Quarterly Samples)

Date	1/21/75		4/15/74		7/9/75	7/16/75	10/14/75	
	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge	River Intake	Pond Discharge
Aluminum, mg/l	1.0	1.5	1.4	2.3	0.7	2.1	0.7	1.7
Ammonia as N, mg/l	0.05	0.45	0.06	0.29	0.07	0.29	0.04	0.14
Arsenic, mg/l	<0.005	0.033	<0.005	0.035	<0.005	0.030	<0.005	0.005
Barium, mg/l	<0.1	<0.1	0.2	0.2	<0.1	<0.1	<0.1	<0.1
Beryllium, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium, mg/l	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001
Calcium, mg/l	13	42	15	42	21	63	19	62
Chloride, mg/l	6	8	4	4	7	5	7	4
Chromium, mg/l	0.012	0.018	0.005	0.016	<0.005	<0.005	<0.005	<0.005
Conductivity, 25°C, umhos/cm	150	410	140	320	150	360	150	420
Copper, mg/l	0.02	<0.01	0.06	0.12	0.08	0.10	0.08	0.09
Cyanide, mg/l	-	<0.01	-	-	-	-	-	-
Hardness, mg/l	46	120	53	110	70	160	64	160
Iron, mg/l	0.84	0.48	1.1	0.30	0.66	0.36	0.45	<0.05
Lead, mg/l	0.018	<0.010	0.032	0.031	<0.010	<0.010	<0.010	0.010
Magnesium, mg/l	3.4	2.7	3.7	1.8	4.2	1.4	4.0	0.4
Manganese, mg/l	0.07	0.13	0.07	0.07	0.07	0.01	0.04	<0.01
Mercury, mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorous, mg/l	0.03	0.03	0.03	-	0.04	0.04	0.04	0.02
Selenium, mg/l	<0.002	0.020	<0.002	0.013	<0.002	0.010	<0.001	0.010
Silica, mg/l	5.1	4.5	5.8	7.1	5.0	9.1	5.3	8.5
Silver, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solids, Dissolved, mg/l	90	260	70	180	90	230	100	140
Solids, Suspended, mg/l	12	11	9	7	5	3	4	3
Sulfate, mg/l	16	6	12	100	9	110	9	67
Zinc, mg/l	0.06	0.04	0.09	0.06	0.03	0.03	0.07	0.02

APPENDIX B

CHLORINE MINIMIZATION PROGRAM FOR ONCE-THROUGH COOLING WATER

APPENDIX B

CHLORINE MINIMIZATION PROGRAM FOR ONCE-THROUGH COOLING WATER

PURPOSE

The purpose of chlorine minimization is to reduce the discharge of chlorine or its related compounds to receiving waters. This description is intended to explain what a chlorine minimization program is and how to develop and implement one. Anticipated situational factors and how to approach them are also presented.

BACKGROUND

Chlorine is commonly added to condenser cooling water of steam electric facilities in order to control the growth of various organisms (algae, bacteria, barnacles, clams) that would otherwise attach to surfaces in the condenser, cooling towers, or to other components of the cooling system and prevent the system from functioning properly.

The attachment of these various organisms to the cooling water system is called biofouling. Since the control method using chlorine involves creating a residual dose of reactive chlorine, some of the chlorine used to control biofouling is still present when the cooling water is discharged from the plant. It is desirable to minimize the discharge of free and combined residual chlorine from steam electric powerplants due to the toxicity these compounds have on aquatic life.

Various powerplants have undertaken some type of program to reduce the use of chlorine. The results of these programs indicate that significant chlorine reduction can be achieved in many cases. Some of the plants found that chlorination is not required at all while others have found that the amount of chlorine added can be significantly reduced, especially during the winter months.

GENERAL APPROACH

In order to determine the minimum amount of chlorine a specific powerplant requires, a chlorine minimization study must be undertaken. A chlorine minimization study may require up to eighteen months. The first step is the selection of the most appropriate minimization strategy, which may take up to six months. During this period, each of the following three variables is controlled at various levels until the minimum value that permits proper plant performance is determined:

1. Dose of chlorine added - where dose is defined as the total amount of chlorine added per unit volume of cooling water.

2. Duration of chlorine addition - where duration is defined as the length of time between the start and end of a single period of chlorine addition.

3. Frequency of chlorination - where frequency is defined as the number of periods of chlorine addition per day or week.

During the trials of various combinations of dose, duration, and frequency, data on plant performance must be collected. These data may include condenser vacuum, generator output, and the cooling water temperature rise as well as pressure drop across the condenser. The performance data can be analyzed to determine if proper plant performance is being maintained. Different plants will necessarily employ different measures of performance to ensure that conditions specific to that plant are taken into account. Starting from operational practices known to maintain satisfactory performance of the cooling system, the systematic approach described in the following sections would be used to select the optimum chlorine minimization strategy. This optimum strategy determines the manner in which dose, duration, and frequency are best varied to maintain system performance.

After the optimal minimization strategy has been determined, a full year of application of the optimal strategy is required to define the minimum dose and duration as well as optimum frquency to be used during any portion of the year. The optimal chlorination procedure will vary with the seasons of the year due to changes in the chemical, physical, and biological characteristics of the cooling water source. Water temperature is an especially important variable, as the growth rate of many microorganisms drops rapidly with decreasing water temperature. Therefore, many plants have found they do not need to chlorinate at all during the winter months.

At the end of a full year of study, the proper chlorination procedure for each season of the year will have been defined and the chlorine minimization program will officially cease. At this point, the proper chlorination procedure is based upon the data collected during the previous years program. System performance data must still be collected periodically to check the adequacy of the procedure and to enable any needed changes to be made.

It is important to mention that plants have some additional ways of reducing chlorine use besides conducting a formal minimization program. For example, chlorine need not always be applied to the entire cooling system. Although biological growth occurs in all segments of the cooling system, the most sensitive portion is usually the condenser. Biological growth in the other segments does not generally impair the operation and efficiency of the plant with the exception of plants with encrustations of macroinvertabrates (barnacles, clams) in the intake system. The relocation of the point of chlorine addition to the condenser inlet box, providing sufficient mixing of chlorine occurs, can result in significant reduction in the quantity of chlorine required to achieve the necessary level of free available chlorine at the condenser outlet. Chlorine addition, however, is required in the cooling water intake structure and other sections of the cooling system for plants with macroinvertabrate fouling problems. Most experience has demonstrated that the continuous application of chlorine is necessary to gain control of both larval and adult forms of the macroinvertabrates where they occur on the intake structure, intake tunnels, and intake water boxes. Chlorine minimization in such instances involves applying chlorine only during the growing season and at the lowest concentrations necessary to achieve control. Visual inspection is the most usual and reliable method of measuring the chlorine effectiveness. For new facilities, the option of utilizing heat treatment to resolve this problem should be explored.

Another method of reducing chlorine use that falls outside the scope of a formal minimization program is the use of a mechanical condenser antifouling device (mechanical cleaning). Some plants using on-line mechanical cleaning do not chlorinate at all; others still require chlorine addition to the critical components of the cooling system. For existing plants, the retrofitting of a mechanical cleaning system may be expensive. For new plants, costs of a mechanical cleaning system are lower since no retrofit is needed. New plants should seriously consider the use of a condenser mechanical cleaning system.

SYSTEMATIC APPROACH FOR DETERMINING MINIMUM AMOUNT OF CHLORINE ADDITION

As explained in the preceeding discussion, the control variables are dose, duration, and frequency. During the optimal strategy development stage, these factors must be varied in a systematic fashion. Throughout this period the operating integrity of the plant must be protected. To accomplish this, plant operators will need to establish some absolute means of monitoring condenser performance. If at all possible, provisions should be made to enable visual inspection of the condenser elements following a test period. The actual condition of the system in terms of biofouling can then be directly compared to the indirect means of monitoring performance (condenser vacuum, pressure drop, etc.). Actual inspection of the condenser or other part of the cooling system (which requires plant closure or loading reduction) should not be considered to be a 'routine' method of evaluating the effectiveness of the chlorine addition program as unit downtime to make such inspections is costly and highly undesirable from the operator's standpoint.

The following sections provide additional details concerning: (1) the specific things each plant must be capable of in order to conduct a minimization program, (2) the specific steps that make up a minimization program, and (3) how a plant should use the results of a minimization program to control future chlorine use.

1. Required Capabilities

a. A means of measuring the apparent waterside condenser tube fouling. This should include visual inspections and biofouling sampling at some point in the test program. Inspection should include the condenser tubes, intake tube sheet, water boxes and, if needed, the cooling water intake structure. Other measurements may be substituted with caution such as deviation from expected condenser vacuum, pressure drop, etc. The substitute measurements all have serious problems of ambiguity since many factors other than biofouling film growth in the condenser tubes can affect these measurements.

b. A means of relating the periodic inspection result or other measurements to condenser performance.

c. A means of gathering grab samples from condenser inlet, outlet, and NPDES discharge point.

d. A means of measuring free available chlorine (FAC) and total residual chlorine (TRC) on samples without delay once collected. The test method to be employed is ASTM D 1253 Chlorine in Water, Method A, Direct Amperometric Titration.

e. A means of controlling and measuring with appropriate accuracy the addition of chlorine to the cooling water to the unit or condenser under study. The arrangement for adding chlorine varies considerably from plant to plant. The physical differences may influence the minimization strategy and may require physical modification of the existing system in order to properly implement the program.

f. General chemical analytical capability for properties or substances in water.

g. A means of determining short-term free available chlorine demand of the inlet water either in the laboratory or by difference between applied chlorine concentration and the free available chlorine residual found at the condenser inlet.

2. Specific Steps in a Minimization Program

a. Establish a baseline of condenser performance associated with the condenser for each seasonal period of plant operation (winter, summer, etc.). This may involve an initial offline chemical or mechanical cleaning. It is necessary that these baseline conditions be used to evaluate the results of the various chlorination strategies. Data needed to establish baseline conditions will be available at most facilities, and thus, will not require a delay in systematic testing of minimization strategies.

b. Conduct screening tests for a length of time to be determined by plant operators. A period of two months for each of the strategies tested is probably appropriate. Different plant cooling water and chlorine feed configurations may require alterations in the selection of the minimization strategies. Plants with several units with similar tube metal, intake water, transit times, temperature gradient across the condensers and cooling water velocity may allow parallel trials of the minimization strategies on several units while maintaining other units on the dose, frequency and duration found effective in past experience. The duration of plant chlorination should be restricted to a maximum of two hours per day.

There are three basic ways to institute a chlorine minimization program: (i) reduce the dose, (ii) reduce the duration, or (iii) change the frequency. For many facilities it may be desirable to conduct all three alternatives in succession prior to selecting the most suitable. In some cases the operator can choose one alternative based on previous experience. The three alternative approaches are explained in detail as follows:

(i) Reduction of Dose: Establish a desired outlet concentration for TRC. This value should be lower than 0.14 mg/l. Maintain the frequency and duration found effective in past experience but reduce the dose of chlorine until the desired effluent concentration is not exceeded. Closely monitor condenser performance parameters during this period. If the system shows signs of biofouling, increase the dose. Test periods of about two months should be used for evaluating effectiveness of each new dose used.

(ii) Reduction of Duration: Decrease the duration of chlorine feed while maintaining the dose and frequency found effective in past experience. Again, test periods of two months are probably adequate to evaluate a particular duration strategy.

(iii) Change the Frquency. Frequency changes with the goal of minimization can be made in two ways: (1) reduce the frequency while keeping dose and duration at baseline values; or (2) increase the frequency but simultaneously decrease the duration. For example, increase frequency from one to three times per day while reducing duration from one hour to 10 minutes. Test periods of two months are probably adequate to evaluate a particular change in frequency.

applied in each season. The optimum combinations for each season being those defined by the chlorine minimization study during that season. Long term year to year variations in water quality may require changes in dose, duration, and frequency not encountered during the minimization test program.

c. Monitoring of condenser performance indicators (condenser vacuum, etc.) should continue during the implementation plan. This is necessary to prevent serious biofouling (and potential plant shutdown) in the event that the influent cooling water quality or plant operating characteristics undergo a sudden change that increases the plant's susceptibility to biofouling.

c. From the short term screening tests, select the approach that appears to best fulfill the purposes of the chlorine minimization program. Using the selected strategy, conduct a year-long trial making appropriate adjustments in the dose, duraiton, and frequency to meet the changing intake water chlorine demand and biofouling propensity so as to maintain acceptable plant performance.

The entire test program, from start to finish, should not require more than 18 months.

3. Using the Results of the Minimization Program

a. The information obtained in the 18 month chlorine minimization program should serve as the guidelines for a permanent chlorination procedure. The most successful approach (the method that provides for adequate plant performance while minimizing chlorine discharge) should be implemented.

b. The implementation program should take into account both year-to-year and seasonal variations in water quality. For example, as was done in the minimization program, each season of the year should be approached as a new set of operating conditions. Different combinations of dose, duration and frequency may be

APPENDIX C

STATISTICAL EVALUATION OF CHLORINE MINIMIZATION AND DECHLORINATION

APPENDIX C

STATISTICAL EVALUATION OF CHLORINE MINIMIZATION AND DECHLORINATION

INTRODUCTION

Chlorine is one of the pollutants identified in the effluent of steam electric generating plants. It is used intermittently in the cooling waters of generating stations to kill organisms which interfere with the operation of a plant. Chlorine is added to the cooling water in batches at such times as biofouling becomes an operational problem. Because chlorination is a batch process, chlorine in a plant's effluent is of concern only during and immediately after the period of chlorination.

The effluent guidelines for steam electric plants are to include standards for chlorine concentrations. Control options which may be applied to reduce effluent chlorine concentrations include chlorine minimization (use of the least amount of chlorine needed without impairing operation of the plant) and dechlorination of the effluent.

Three plants have provided data to EPA on chlorine concentrations under no-control, minimization and dechlorination (where dechlorination may include some level of chlorine minimization as well) to the EPA. The purpose of the analysis of this data is to describe the performance of these treatment methods, and to establish standards for the discharge of chlorine.

Recommended Standards

The analysis performed on this data was to determine limitations on the maximum measured concentration. Agency policy is to base such limitations on the 99th percentile of the distribution of daily effluent concentrations. The 99th percentile estimates have been computed for each plant, within each level of treatment. These values are the concentration recommended for chlorine limitation. (See text for further explanation.)

Table 1

Recommended Standards: TRC (mg/l)

Treatment Type:	No Controls	0.34
	Chlorine Minimization	0.20
	Dechlorination	0.14

Descriptive Statistics

The data are from three steam electric generating plants in Michigan and cover the period from January 1977 through December 1978. The data include periods of no controls on chlorine (January-May 1977), chlorine minimization only (June-October 1977) and dechlorination (November 1977-December 1978). Data exist for each plant, for each day on which the plant performed chlorination. A single chlorination event is defined as any period in which chlorine is added to the cooling waters of a steam electric generating plant. For each chlorination event, a number of analyses of the effluents is performed. For each event, the following aggregate statistics were provided to the EPA: the number of samples taken, the maximum and minimum value of the effluent concentration and the average of the sample values. The number of distinct samples for each chlorination event ranges from 1 to over 20, with an average value of 6.24 samples/chlorination event. Concentrations of chlorine levels in the effluent are reported in milligrams per liter (mg/l) as Total Residual Chlorine (TRC).

Data for the most part, were used as they appeared on the monitoring reports of the plants. Three data points were deleted because they were taken on days of known equipment malfunctions; a fourth point was removed because of an apparent reporting error (the dates of edited points were 6/1/77, 7/10/77, 9/30/77 and 10/29/77). The number of chlorination events, for each plant, and within each level of treatment is reported in table 2.

Table 2

The Number of Chlorination Events

Treatment	Plant 2608	Plant 2607	Plant 2603
No Controls	56	44	103
Chlorine Minimization	58	94	87
Dechlorination	52	183	261
Total	166	331	451

The form in which the data were reported (minimum, maximum, average, and number of samples taken), as well as the character of the data, limits the kinds of analyses that can be performed on this data. Often, observations of pollutant levels are log normally distributed. The chlorine levels for the maximum, minimum and average values reflect a high degree of skewness, illuminating the fact that this data does not arise from a log normal distribution.

If the underlying distribution were log normal, it would be a truncated log normal, with a large probability mass at zero. In table 3, the occurrence of the large percentage of zero values is made explicit.

Table 3

Percentage of Average ($\bar{X}$) and Maximum (Max.) Values Equaling Zero

Treatment	Plant 2608		Plant 2607		Plant 2603	
	% of $\bar{X}$	% of Max	% of $\bar{X}$	% of Max	% of $\bar{X}$	% of Max
No Controls	3.6	3.6	15.9	15.9	0	0
Chlorine Minimization	3.4	0	25.5	18.1	2.3	2.3
Dechlorination	75.0	51.9	54.9	49.7	52.1	51.7
Total	25.9	17.5	41.4	36.3	30.6	30.4

Without imposing strict distributional requirements on this data, it may be asserted that the data (both maximum and average values) are highly skewed in favor of the lower tail, with the level of skewness increasing with more stringent controls. Histograms and plots of the empirical distribution function provide evidence of large skewness. The histograms for Plants 2608, 2607 and 2603 are shown in figures 1, 2 and 3 respectively. Each figure consists of six histograms (labeled a through f) as follows:

a - Histogram of maximum TRC values with no controls.

b - Histogram of average TRC values with no controls.

c - Histogram of maximum TRC values with chlorine minimization.

d - Histogram of average TRC values with chlorine minimization.

e - Histogram of maximum TRC values with dechlorination.

f - Histogram of average TRC values with dechlorination.

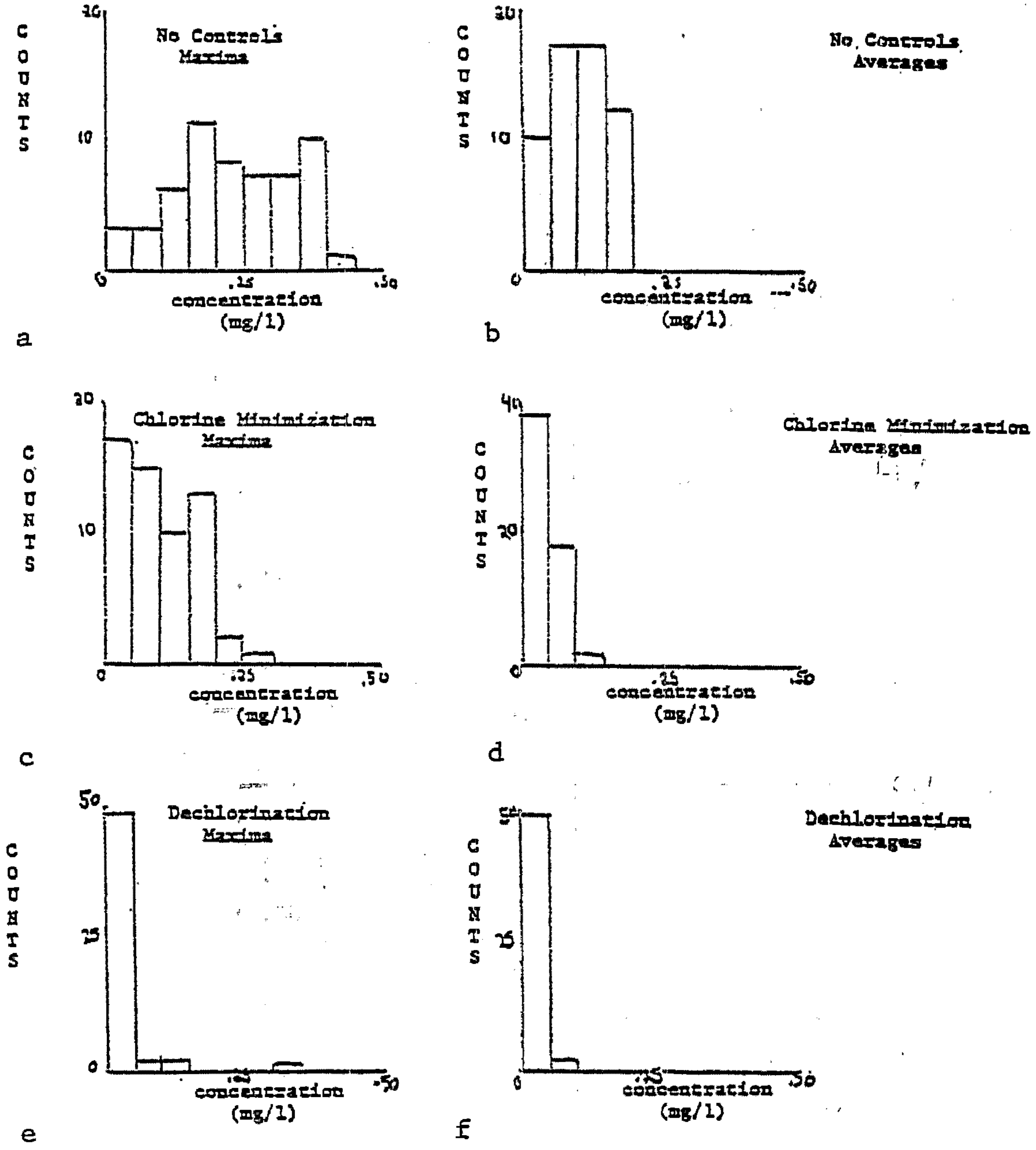

Figure 1

HISTOGRAMS FOR PLANT 2608

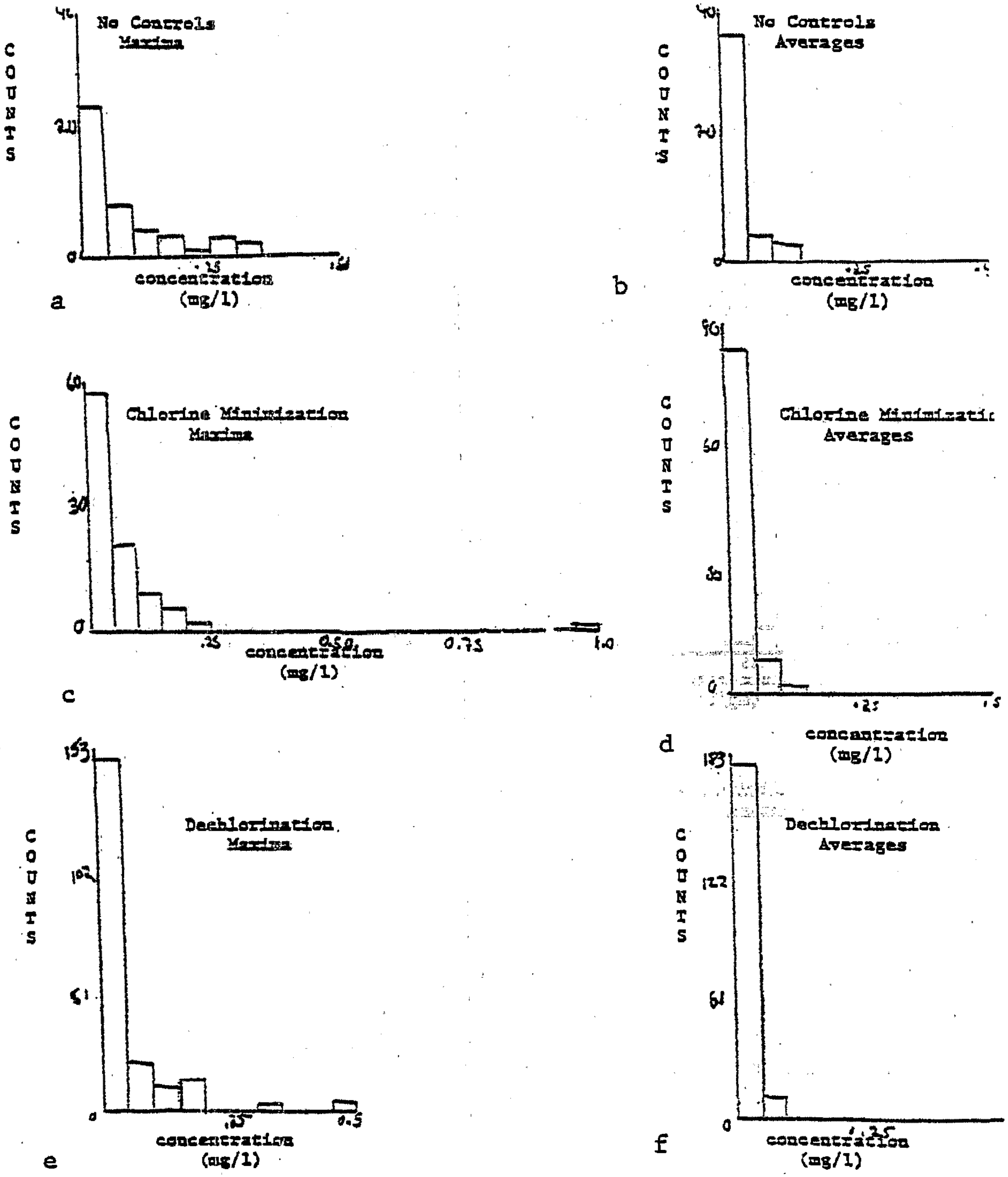

Figure 2

HISTOGRAMS FOR PLANT 2607

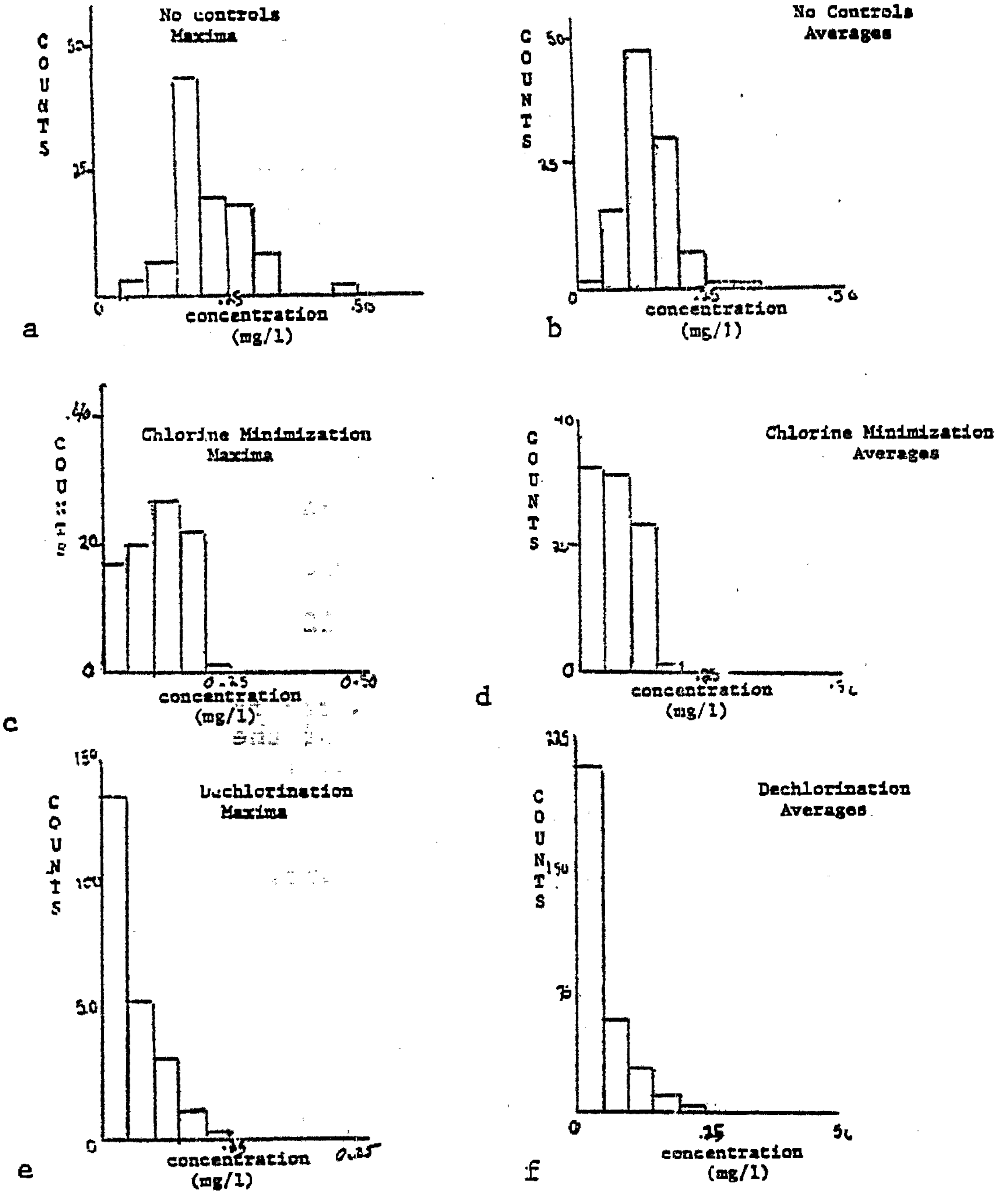

Figure 3

HISTOGRAMS FOR PLANT 2603

The empirical distribution functions for Plants 2608, 2607 and 2603 are shown in figures 4, 5 and 6, respectively. Each figure consists of six distribution functions (labeled a through f) in the same format as the histograms.

The data were investigated for long term average performance. From the information reported by the plant, a weighted mean has been computed. This estimate is based on the number of samples taken for any single chlorination event, and the average for the chlorination event. The mean has been computed for each plant, within each level of treatment.

Table 5

Weighted Mean: TRC (mg/l)

Treatment	Plant 2608	Plant 2607	Plant 2603
No Controls	.1047	.0264	.1459
Chlorine Minimization	.0392	.0150	.0765
Dechlorination	.0080	.0122	.0375

Since the data are reported in this aggregated form, the conventional estimator of the standard deviation of the chlorine measurement can not be applied. Assumed that:

$$\text{Var } X_{ij} = \sigma^2$$

And that the X_{ij} are statistically independent. It follows that an unbiased estimator of σ^2 is:

$$S^2 = \left\{ \sum_{i=1}^{I} (\bar{X}_i - \bar{\bar{X}})^2 / (1/n_i - 1/\sum_i n_i) \right\} / I$$

where n_i = the number of observations for the ith chlorination event. Estimates of σ are presented in table 6.

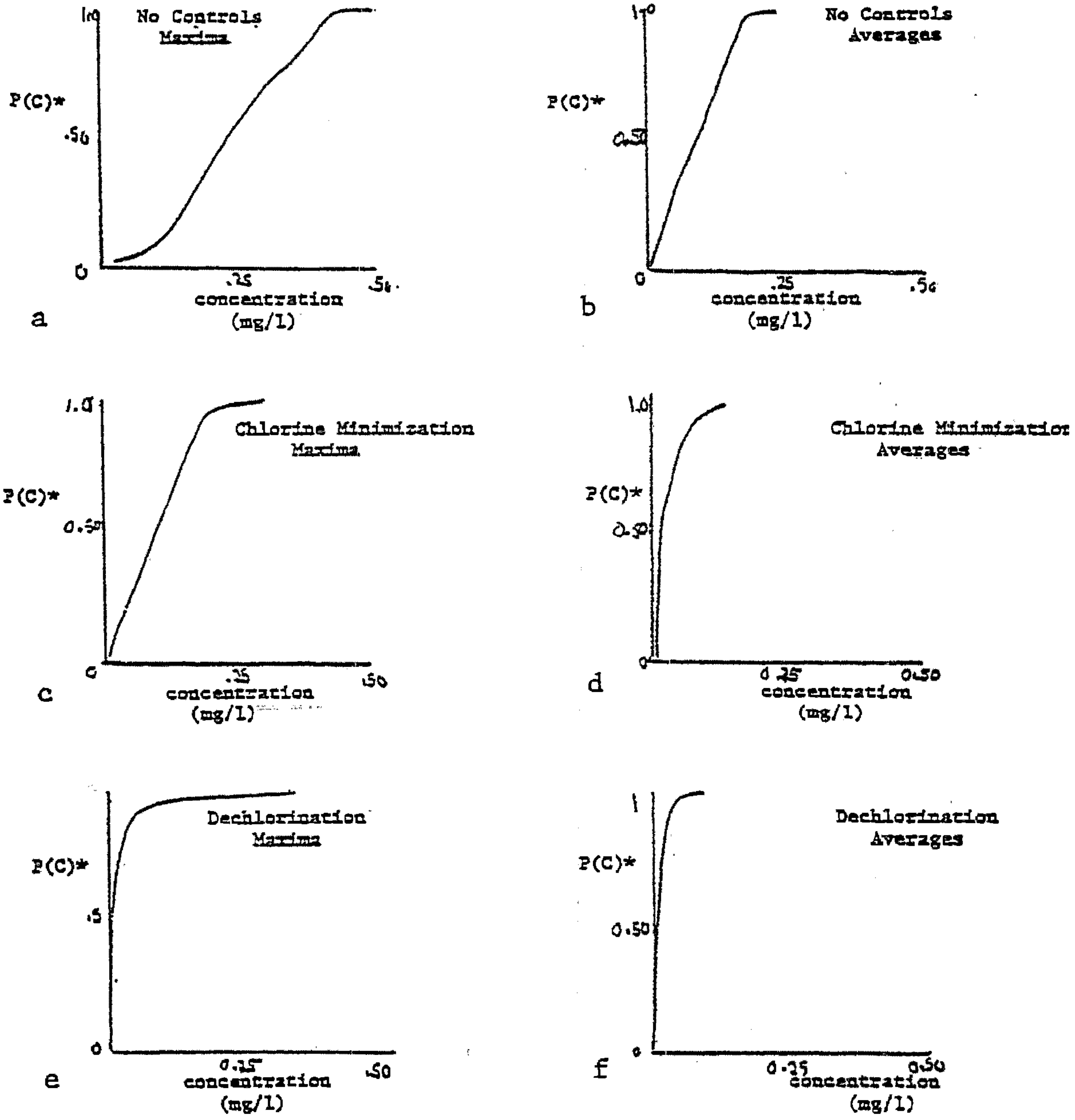

Figure 4

EMPIRICAL DISTRIBUTION FUNCTIONS FOR PLANT 2608

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*P(C) = proportion less than are equal to concentration C.

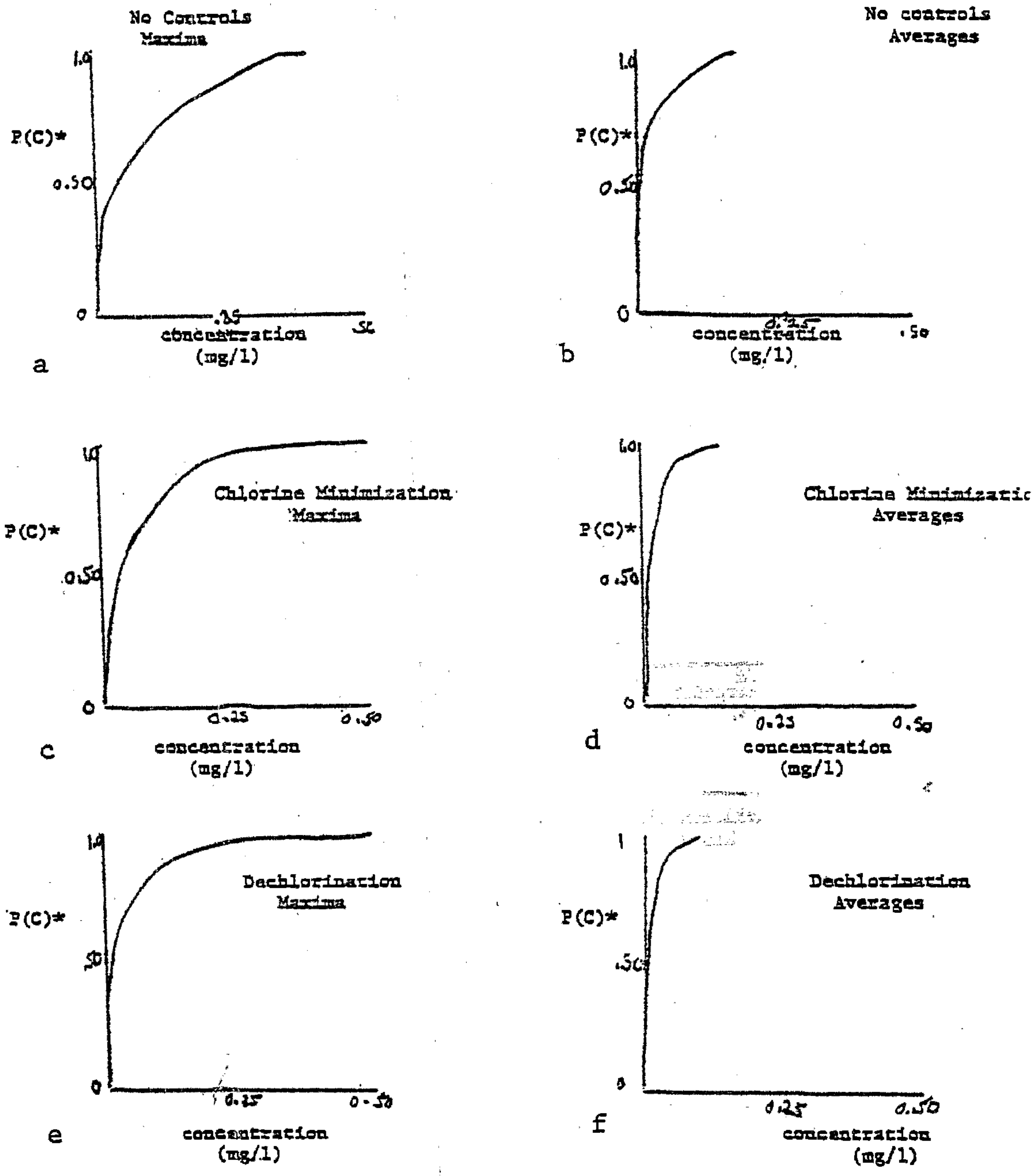

Figure 5

EMPIRICAL DISTRIBUTION FUNCTIONS FOR PLANT 2607

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*P(C) = proportion less than or equal to concentration C.

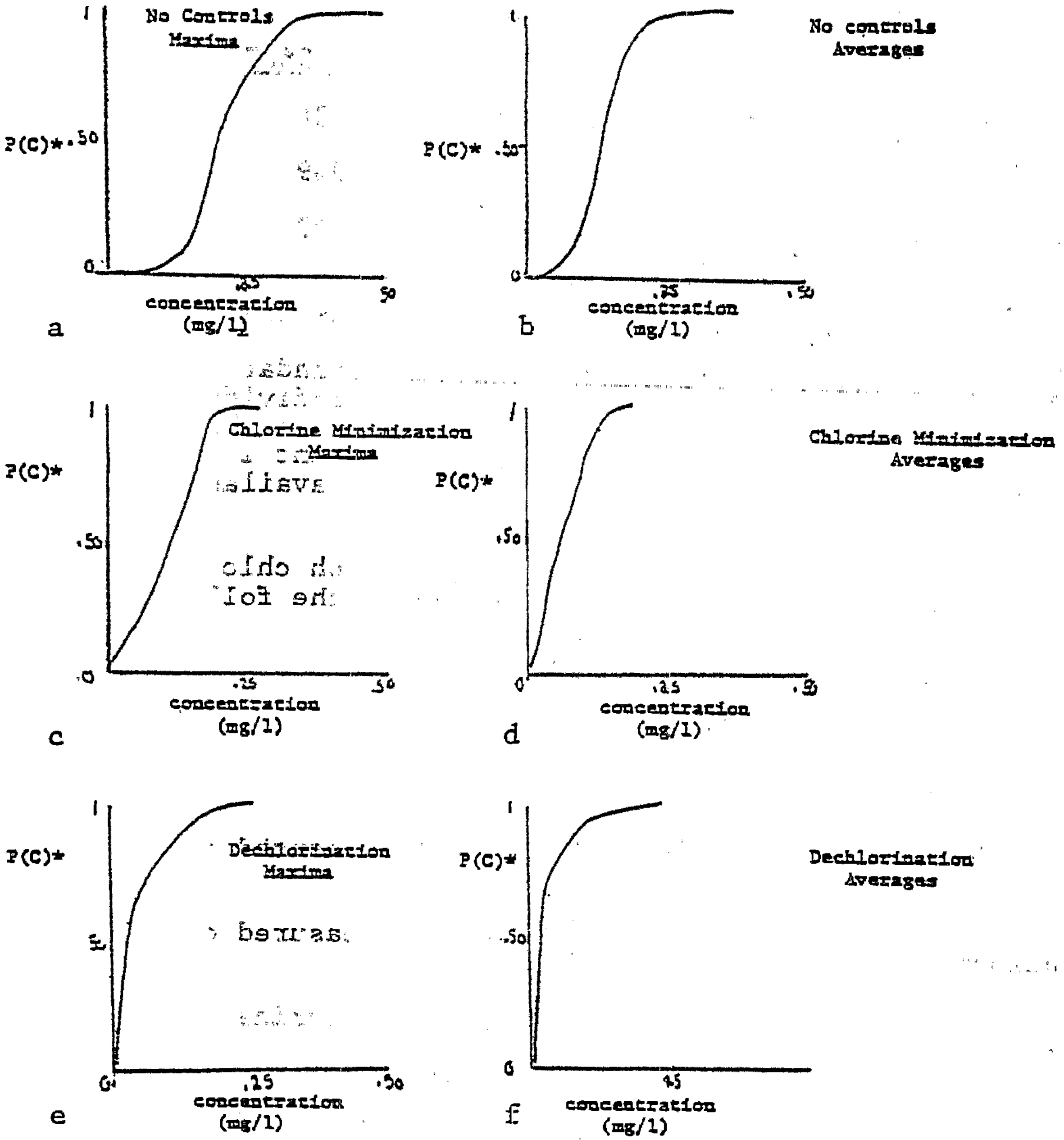

Figure 6

EMPIRICAL DISTRIBUTION FUNCTION FOR PLANT 2603

*P(C) = proportion less than or equalt to concentration C.

Table 6

Standard Deviation

Treatment	Plant 2608	Plant 2607	Plant 2603
No Controls	.7257	.3834	.4531
Chlorine Minimization	.1774	.2349	.2663
Dechlorination	.0912	.2307	.4218

The medians and grand means for the results are found in table 7.

The computation for the estimate of the standard deviation is not as straight-forward as the mean, because individual sample points are not known. For a given plant, let X_{ij} be the observed chlorine concentration for chlorination event i and for $j = 1, 2, \ldots n_i$. For each chlorination event, the available data are as follows:

1. The mean TRC concentration of each chlorination event ($\bar{X}_i$), where the mean is calculated using the following equation:

$$\bar{X}_i = 1/n_i \sum_{j=1}^{n_i} X_{ij}$$

2. The maximum TRC concentration measured during each chlorination event (X_{ij} max).

3. The minimum TRC concentration measured during each chlorination event (X_{ij} min).

4. The number of samples collected during each chlorination event (n_i).

Table 7

Weighted Means and Median of Estimated Standard Deviation for Treatment Type (Plant Independent)

Treatment	Median	Mean
No Controls	.4531	.4765
Chlorine Minimization	.2349	.2398
Dechlorination	.2307	.2972

Derivation of Recommended Standards

A daily maximum permissible value is generally based on estimates of the 99th percentile of the distribution of effluent concentrations. It is hypothesized that $X_{ij} \sim F_o$ (F_o is unspecified). The 99th percentile is defined as x_o such that $F_o(x_o) = .99$ ($x_o = F_o^{-1}[.99]$).

$$I_i\ (X_{(n_i)}) = \begin{bmatrix} 1 & X_{(n_i)} < x_o \text{ where } X_{(n_i)} \\ & \text{is the maximum observation} \\ & \text{for the ith chlorination event.} \\ 0 & \text{Otherwise} \end{bmatrix}$$

It is noted that if $X_{(n_i)} < x_o$, then for that chlorination event, all $X_{ij} < x_o$. Hence:

$$E\ (I_i) = .99^{ni}$$

x_o is estimated for each plant by selecting that value such that

$$E\ (\sum_i I_i) = E\sum_i (I_i) = \sum_i .99^{ni}$$

The nearest integer greater than or equal to $\Sigma_i .99^{ni}$ is the rank of that data value (among the set of maximum values) which will be set equal to x_o. Therefore, I_i, defined relative to x_o satisfies the condition that $\Sigma_i I_i$ (in expectation) = $\Sigma_i .99^{ni}$. The estimation procedure required solving for $\Sigma_i .99^{ni}$, ranking the data values within a treatment type and within a plant and assigning to x_o, that value whose rank is $[\Sigma_i .99^{ni}]$. The ranks and the 99th percentile estimates for daily maxima appear in table 8 and 9 respectively.

Table 8

Computation of $\sum_i .99^{n_i}$

Treatment	Plant 2608	Plant 2607	Plant 2603
No Controls	51.83	40.45	99.27
Chlorine Minimization	53.40	86.97	83.27
Dechlorination	49.38	179.32	246.46

Table 9

99th Percentile Estimates for a Daily Maximum

Treatment	Plant 2608	Plant 2607	Plant 2603
No Controls	.38	.30	.34
Chlorine Minimization	.20	.20	.20
Dechlorination	.09	.16	.14

(Note that all data points are reported accurately to the second decimal place, hence, percentile points based on the observed data will be reported as a two digit number. However, an improvement could be made, albeit slight, if an interpolation procedure were applied to the data point associated with the observed value of $\sum_i .99^{n_i}$ and the adjusted value of that quantity.)

Our final recommendation is to use the medians, across plant, of the 99th percentile points, as the standard. These standards are reported in table 1.