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Supplement For PRETREATMENT to the Development Document for the

STEAM ELECTRIC POWER GENERATING

Point Source Category

U.S. ENVIRONMENTAL PROTECTION AGENCY

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SUPPLEMENT FOR PRETREATMENT
TO THE DEVELOPMENT DOCUMENT

for the

STEAM ELECTRIC POWER GENERATING
POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of that section of the Steam Electric Power Generating Industry which discharges industrial wastes to publicly owned treatment works (POTW). Its purpose is to develop pretreatment standards to implement section 307(b) of the Federal Water Pollution Control Act Amendment of 1972 for the Existing Power Plants.

Pretreatment standards, recommended in Section II of this report set forth the degree of effluent reduction achievable through the application of control technology currently available for those pollutants which are determined not to be susceptible to treatment by a POTW or which would interfere with the operation of such works. These pretreatment standards set forth the degree of effluent reduction achievable through application of the available demonstrated control technology, processes, operating methods, or other alternatives. These standards must be achieved no later than three (3) years from the date of promulgation.

Supporting data and rationale for development of pretreatment standards are contained in this report.

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SECTION I

CONCLUSION

An engineering evaluation of steam electric power generating plants that discharge all or a portion of their aqueous wastes to publicly-owned treatment works (POTW) was conducted to establish the basis for pretreatment standards. For the purpose of establishing such standards it was deemed practical to divide the wastes from power plants into the following waste-types:

- Condenser Cooling System
- Boiler Water Treatment
- Boiler Blowdown
- Maintenance Cleaning
- Ash Handling
- Drainage
- Air Pollution Control Devices
- Miscellaneous Waste Streams

This division is identical to that presented in the development document for direct dischargers (14) in this industry with the deletion of Construction Activity. This division was found to be valid as examination of process characteristics and raw wastes were not found to be significantly different from those of direct dischargers.

Conduct of the work involved contact with 49 steam electric power generating stations, representing 50 percent of the estimated 98 stations discharging chemicals wastes to a POTW. Engineering visits and data collection were made to 23 stations. Sampling of raw and pretreated wastes was obtained from eight (8) stations. Additionally, prior work conducted by the EPA, data collected in response to NPDES and local discharge permit monitoring, industrial effluent data, and relevant literature prepared by the EPA and electrical trade journals were evaluated.

Based on the above evaluation, the following conclusions were reached:

- Pollutants discharged by the population of plants discharging to the POTW are similar to those of direct dischargers.
- The division of waste types developed above is valid for the purpose of characterizing the waste sources.

- Treatment technologies described in the development document for the effluent limitations guidelines for this industry are also applicable to plants discharging to the POTW.

A survey of current industry practices has indicated that most plants provide little pretreatment of chemical type wastes at the present time. Based upon information provided in this document regarding pollutant properties and raw waste characteristics, it is determined that some of the pollutants discharged by the Steam Electric Power Generating Point Source Category will interfere with or be treated inadequately by Publicly Owned Treatment Works (POTW).

SECTION II

RECOMMENDATIONS

As a result of the findings and conclusions contained in this report, the pretreatment standards for existing power plants in compliance with the mandates of the Federal Water Pollution Control Act Amendment of 1972 are summarized below:

General Unit Subcategory*

For the purpose of establishing pretreatment standards under Section 307(b) of the Act for a source within the General Unit subcategory, the provisions of 40 CFR 128 shall not apply. The pretreatment standards for an existing source within the general unit subcategory are set forth below.

(a) No pollutant (or pollutant property) introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

(1) Pollutants which create a fire or explosion hazard in the publicly owned treatment works.

(2) Pollutants which will cause corrosive structural damage to treatment works, but in no case pollutants with a pH lower than 5.0, unless the works is designed to accommodate such pollutants.

(3) Solid or viscous pollutants in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works.

(4) Pollutants at either a hydraulic flow rate or pollutant flow rate which is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

(b) In addition to the general prohibitions set forth in paragraph (a) above, the following pretreatment standard establishes the quality or quantity of pollutants or pollutant properties controlled by this section which may be introduced into a publicly owned treatment works by a source subject to the provisions of this subpart.

(1) There shall be no discharge to publicly owned treatment works of polychlorinated biphenol compounds such as those used for tranformer fluid.

(2) The quantity of copper discharged in metal cleaning wastes to publicly owned treatment works shall not exceed the quantity determined by mulitplying the flow of metal cleaning wastes times 1 mg/l.

(3) The quantity of oil and grease in the plant's combined discharge to the publicly owned treatment works shall not exceed the quantity determined by multiplying the flow of the combined discharge times 100 mg/l.

(c) Any owner or operator of any source to which the pretreatment standards required by paragraph (a) above are applicable, shall be in compliance with such standards upon the effective date of such standards. The time for compliance with standards required by paragraph (b) above shall be within the shortest time but not later than three years from the effective date of such standards.

Small Unit Subcategory*

For the purpose of establishing pretreatment standards under Section 307(b) of the Act for a source within the Small Unit subcategory, the provisions of 40 CFR 128 shall not apply. The pretreatment standards for an existing source within the small unit subcategory are set forth below.

(a) No pollutant (or pollutant property) introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

(1) Pollutants which create a fire or explosion hazard in the publicly owned treatment works.

(2) Pollutants which will cause corrosive structural damage to treatment works, but in no case pollutants with a pH lower than 5.0, unless the works is designed to accommodate such pollutants.

(3) Solid or viscous pollutants in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works.

(4) Pollutants at either a hydraulic flow rate or pollutant flow rate which is excessive over relatively short

time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

(b) In addition to the general prohibitions set forth in paragraph (a) above, the following pretreatment standard establishes the quality or quantity of pollutants or pollutant properties controlled by this section which may be introduced into a publicly owned treatment works by a source subject to the provisions of this subpart.

(1) There shall be no discharge to publicly owned treatment works of polychlorinated biphenol compounds such as those used for tranformer fluid.

(2) The quantity of copper discharged in metal cleaning wastes to publicly owned treatment works shall not exceed the quantity determined by mulitplying the flow of metal cleaning wastes times 1 mg/l.

(3) The quantity of oil and grease in the plant's combined discharge to the publicly owned treatment works shall not exceed the quantity determined by multiplying the flow of the combined discharge times 100 mg/l.

(c) Any owner or operator of any source to which the pretreatment standards required by paragraph (a) above are applicable, shall be in compliance with such standards upon the effective date of such standards. The time for compliance with standards required by paragraph (b) above shall be within the shortest time but not later than three years from the effective date of such standards.

Old Unit Subcategory*

For the purpose of establishing pretreatment standards under Section 307(b) of the Act for a source within the Old Unit subcategory, the provisions of 40 CFR 128 shall not apply. The pretreatment standards for an existing source within the old unit subcategory are set forth below.

(a) No pollutant (or pollutant property) introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

(1) Pollutants which create a fire or explosion hazard in the publicly owned treatment works.

(2) Pollutants which will cause corrosive structural damage to treatment works, but in no case pollutants with a pH lower than 5.0, unless the works is designed to accommodate such pollutants.

(3) Solid or viscous pollutants in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works.

(4) Pollutants at either a hydraulic flow rate or pollutant flow rate which is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

(b) In addition to the general prohibitions set forth in paragraph (a) above, the following pretreatment standard establishes the quality or quantity of pollutants or pollutant properties controlled by this section which may be introduced into a publicly owned treatment works by a source subject to the provisions of this subpart.
(1) There shall be no discharge to publicly owned treatment works of polychlorinated biphenol compounds such as those used for tranformer fluid.

(2) The quantity of copper discharged in metal cleaning wastes to publicly owned treatment works shall not exceed the quantity determined by mulitplying the flow of metal cleaning wastes times 1 mg/l.

(3) The quantity of oil and grease in the plant's combined discharge to the publicly owned treatment works shall not exceed the quantity determined by multiplying the flow of the combined discharge times 100 mg/l.

(c) Any owner or operator of any source to which the pretreatment standards required by paragraph (a) above are applicable, shall be in compliance with such standards upon the effective date of such standards. The time for compliance with standards required by paragraph (b) above shall be within the shortest time but not later than three years from the effective date of such standards.

Area Runoff Subcategory*

For the purpose of establishing pretreatment standards under Section 307(b) of the Act for a source within the Area Runoff subcategory, the provisions of 40 CFR 128 shall not apply. The pretreatment standards for an existing source within the area runoff subcategory are set forth below.

(a) No pollutant (or pollutant property) introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

(1) Pollutants which create a fire or explosion hazard in the publicly owned treatment works.

(2) Pollutants which will cause corrosive structural damage to treatment works, but in no case pollutants with a pH lower than 5.0, unless the works is designed to accommodate such pollutants.

(3) Solid or viscous pollutants in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works.

(4) Pollutants at either a hydraulic flow rate or pollutant flow rate which is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

(b) Any owner or operator of any source to which the pretreatment standards required by paragraph (a) above are applicable, shall be in compliance with such standards upon the effective date of such standards.

*The definitions of these subcategories are the same as those used for the effluent limitations guidelines regulations.

SECTION III

INTRODUCTION

General Background

The involvement of the Federal Government in water pollution control dates back to 1948 when Congress enacted the first comprehensive measure aimed specifically at this problem. At that time the Surgeon General, through the U.S. Public Health Service, was authorized to assist states in various ways to address the problem. The emergence of a national water pollution control program came about with the enactment of the Water Pollution Control Act of 1956 (Public Law 84-660). To date this law remains the basic law governing water pollution. It establishes the basic system of technical and financial assistance to states and municipalities, as well as enforcement procedures by which legal steps can be initiated against polluters.

The present program dates back to the Water Quality Act of 1965 and the Clean Water Restoration Act of 1966. Under the 1965 Act, states were required to adopt water quality standards for interstate waters, and to submit to the Federal Government, for approval, plans to implement and enforce these standards. The 1966 Act authorized Federal participation in construction of sewage treatment plants. On amendment, the Water Quality Act of 1970, extended Federal activities into such areas as pollution by oil, hazardous substances, sewage from vessels, and mine drainage.

Originally, pollution control activities were the responsibility of the U.S. Public Health Service. In 1961, the Federal Water Pollution Control Administration (FWPCA) was created in the Department of Health, Education and Welfare, and in 1966, the FWPCA was transferred to the Department of the Interior. The name was changed in early 1970 to the Federal Water Quality Administration and in December 1970, the Environmental Protection Agency (EPA) was created by Executive Order as an independent agency outside the Department of the Interior. Executive Order 11574 on December 23, 1970, established the Permit Program, requiring all industries to obtain permits for discharge of wastes into navigable waters or their tributaries under the provisions of the 1899 River and Harbor Act (Refuse Act). The permit program immediately became involved in legal problems resulting in a court ruling that effectively stopped issuance of a significant number of permits. It did result in the filing with EPA, through the U.S. Army Corps of Engineers, of applications for permits which, represent a complete inventory of industrial waste discharges. The granting of a permit under the Refuse Act was dependent on the discharge being able to meet applicable water quality standards. Although EPA could not specify methods of treatment, they could require minimum effluent levels necessary to meet water quality standards.

The Federal Water Pollution Control Act Amendments of 1972 (the "Act") made a number of fundamental changes in the approach to achieving clean water. One of the most significant changes was from a reliance on water quality related effluent limitations to a direct control of effluents through the establishment of technology-based effluent guidelines to form an additional basis, as a minimum, for issuance of discharge permits. The permit program under the 1899 Refuse Act was placed under full control of EPA, with much of the responsibility to be delegated to the States.

PURPOSE AND AUTHORITY

Under the Act, the Environmental Protection Agency is charged with establishing pretreatment standards to protect the operation of publicly-owned treatment works and to prevent discharge of pollutants which pass through such works inadequately treated.

As part of this Act, Section 307(b) states that the Administrator shall "publish proposed regulations establishing pretreatment standards for introduction of pollutants into treatment works (as defined in Section 212 of this Act) which are publicly owned for those pollutants which are determined not to be susceptible to treatment by such treatment works or which would interfere with the operation of such treatment works. Pretreatment standards under this section shall specify a time for compliance not to exceed three years from the date of promulgation."

This report is prepared for the purpose of developing pretreatment standards for existing sources. Pretreatment standards for new sources have been promulgated October of 1974, (together with the effluent limitations guidelines for the Steam Electric Power Generating Point Source Category).

SCOPE OF WORK AND TECHNICAL APPROACH

The pretreatment standards proposed herein were developed in the following manner. A comprehensive survey was conducted of over 1200 steam electric generating stations in the United States. The stations were screened in two stages: (1) the entire population was screened and cross-matched using available references and (2) 230 stations were contacted by telephone. The list of plants that discharge to a POTW was first studied for the purpose of determining whether separate standards would be required for different divisions within the list. The analysis was based upon fuels used, size production process employed, wastewater pretreatment at plant sites, and other factors. The raw waste characteristics for each subcategory were then identified. This included an analyses of (1) the source and volume of water used in the process employed (2) the constituents (including thermal) of all wastewaters including constituents which result in taste, odor, and color in water, (3) the effect of the constituent on the operation of the POTW and (4) the adequacy of the POTW in treatment of such constituents. Wastewaters which should be subject to pretreatment standards were identified.

The full range of control and pretreatment technologies existing within each subcategory was identified. This included identification of each distinct control and pretreatment technology, including both in-plant and end-of-process technologies, which are existent or capable of being designed for each division. It also included an identification of the amount of constituents and the chemical, physical, and biological characteristics of pollutants. Effluent levels resulting from the application of each of the pretreatment and control technologies were also identified. The problems, limitations, and reliability of each pretreatment and control technology were also identified. In addition, the nonwater quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, and solid waste, were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology are available for effluent reduction. In identifying such technologies, various factors were then considered. These included the total cost of application of technology, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, nonwater quality environmental impact (including energy requirements), and other factors.

Data for identification and analyses were obtained from a number of sources. These sources included EPA research information; EPA, state, and local environmental personnel; trade associations; published literature; qualified technical consultation; historical information on effluent quality and quantity; and on-site visits including analytical programs and interviews at steam electric plants throughout the United States which were known to have above average waste pretreatment facilities. All references used in developing the pretreatment standards reported herein are listed in Section XI of this document.

Twenty-three operating plants were visited and eight were sampled. Composite samples over a sixteen hour period were obtained from these eight plants and were analyzed for parameters mentioned in Section V. Information was obtained from as many as fifteen (15) plants for each waste-type division. Both in-process and end-of-pipe data were obtained as a basis for determining water use rates capabilities and effluent loads. Permit application data was of value for the purposes of this study when such data covered outfalls serving only steam electric power operations.

Cost information was obtained directly from industry during plant visits, from engineering firms, equipment suppliers, and from the literature. These costs have been used to develop general capital, operating, and total costs for each pretreatment and control method. This generalized cost data and specific information obtained from plant visits was used to estimate cost effectiveness in Section VIII and elsewhere in this report.

Certain plants were selected for in-depth analysis from the total population of those visited. These plants were plants discharging representative waste types or employing above average treatment technology or having substantial quantities of historic effluent data.

The following selection criteria were developed and used for selection of plants visited and sampled.

1. Representative plant with respect to fuel type, size, geographical location and other factors.

2. Plants that discharge types or quantities of waste representative of those delineated in Section IV.

   Plants that have treatment.

GENERAL DESCRIPTION OF THE INDUSTRY

The Steam Electric Power Industry is made up of 1273 plants throughout the contiguous United States. Of these plants an estimated 7.7 percent or 98 plants discharge wastewaters to publicly-owned treatment works and are thus covered by the scope of this document. In this study 49 plants discharging to POTW were contacted.

Statistics for this section were estimated based on a truly random sampling of steam electric power plants contained in the "Environmental Assessment of Alternative Thermal Control Strategies for the Electric Power Industry" by Michelle M. Zarubica of the Office of Planning and Evaluation of the Environmental Protection Agency (18).

Steam Electric plants discharging to the POTW tended to be smaller on the average than plants discharging to surface water. These plants averaged about 150 MW for a total capacity of 14,500 MW which compares with an average capacity and total generating capacity of about 400 MW and 506,700 MW for the entire Steam Electric Industry. (See Tables III-1 and III-2). Of these plants, an estimated 72 percent are publicly-owned and 28 percent are investor owned.

Most of the Steam Electric plants that discharge to POTW (68 percent) use gas as their principal fuel compared to 31 percent for the entire industry (Figures III-1 and III-2). Conversion of some plants from gas to oil is expected due to shortage of natural gas.

Plants which discharge wastewaters to POTW tend to have units older than plants which discharge to surface waters. Tables III-1 and III-2 show that 29 percent of the plants which discharge to POTW were built since 1960 as compared to 38 percent for the entire population. Also, plants built since 1960 represent 48 percent of the generating capacity of plants discharging to POTW compared to 78 percent for the entire Steam Electric Industry. (See Figures III-3 and III-4).

Approximately 24 percent of all electrical generation is nuclear powered but no plants of this type were observed to discharge to the POTW. Nonetheless, nuclear plants are included in this document, since their chemical waste discharges are similar in nature to those discharged by non-nuclear facilities (14).

Steam Electric plants discharging to POTW are located in all regions of the country with somewhat higher than average concentrations in the Midwest and in California.

Process Description

The "production" of electrical energy involves utiliation and conversion of chemical or nuclear energy. Present day methods of utilizing energy of fossil fuels are based on a

Table III-1. TOTAL STEAM ELECTRIC PLANTS IN THE CONTIGUOUS UNITED STATES

Total Number of Plants = 1273
Total Number of Units = 3011
Total Number of Megawatts= 506,654
Average Station Size = 398
Percentage of Plants Confirmed as Discharging to Municipal Sewers - by Number = 7.7%
by Megawatts = 2.9%

Principal Unit Fuel	Percentage by Number	Percentage by Megawatts
Gas	31.0	12.6
Oil	14.6	14.0
Coal	49.3	49.6
Nuclear	5.1	23.8
	100.0	100.0

Unit Built In	Percentage by Number	Percentage by Megawatts
1970's	17.6	57.6
1960's	20.3	20.1
1950's	36.1	17.6
1940's	16.0	3.7
1930's	6.5	0.8
1920's	2.7	0.1
1910's	0.8	0.1

Table III-2. STEAM ELECTRIC PLANTS DISCHARGING TO MUNICIPAL SEWERS IN THE CONTIGUOUS UNITED STATES

Total Number of Plants = 98
Total Number of Units = 277
Total Number of Megawatts = 14504
Average Station Size = 148

Principal Unit Fuel	Percentage by Number	Percentage by Megawatts
Gas	67.7	44.1
Oil	17.7	54.0
Coal	14.7	1.9
Nuclear	0.0	0.0
	100.0	100.0

Unit Built In	Percentage by Number	Percentage by Megawatts
1970's	5.9	4.3
1960's	23.5	43.2
1950's	35.3	47.0
1940's	23.5	5.2
1930's	5.9	0.2
1920's	5.9	0.1
1910's	0.0	0.0
	100.0	100.0

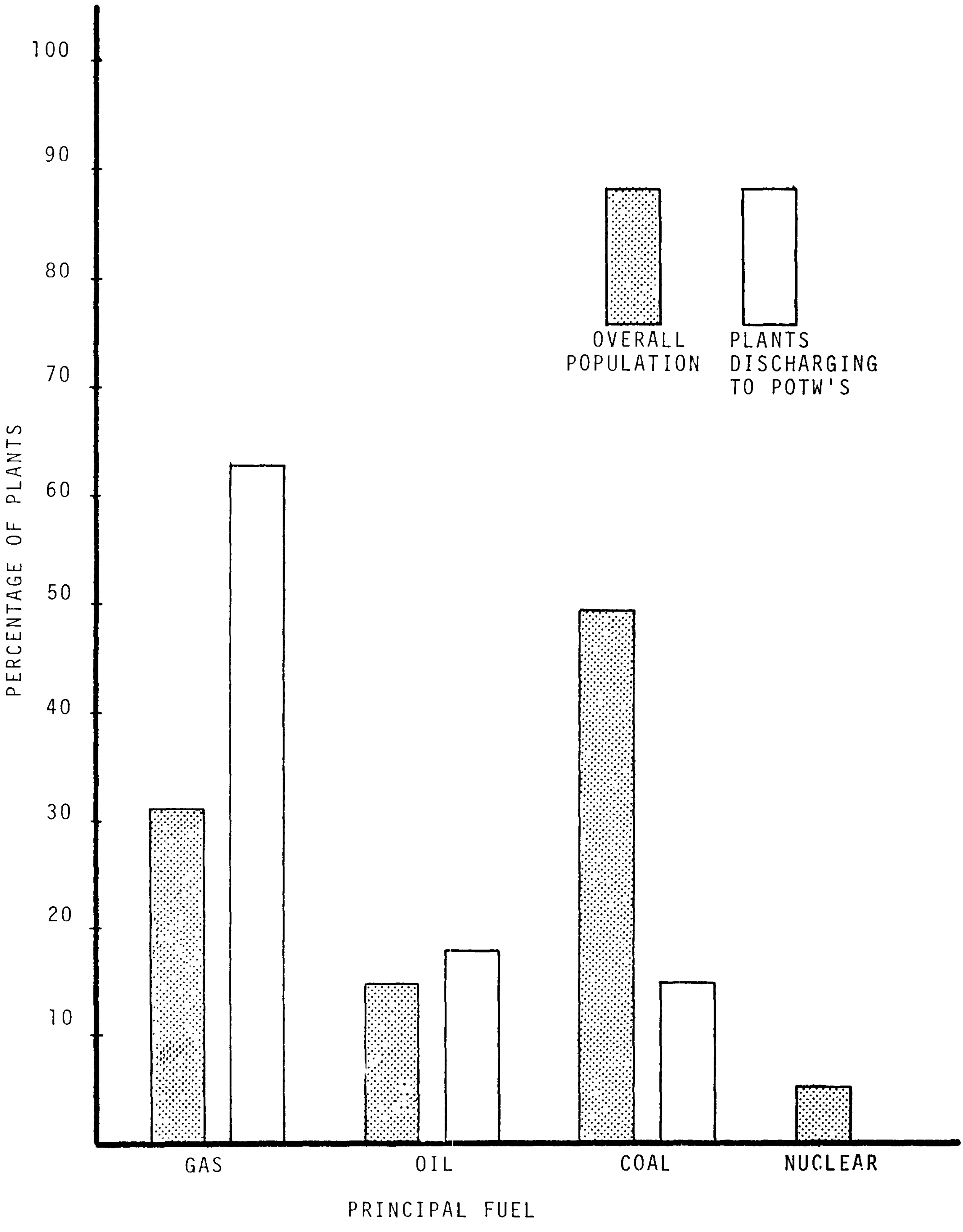


FIGURE III-1. Principal Fuel Use by Number

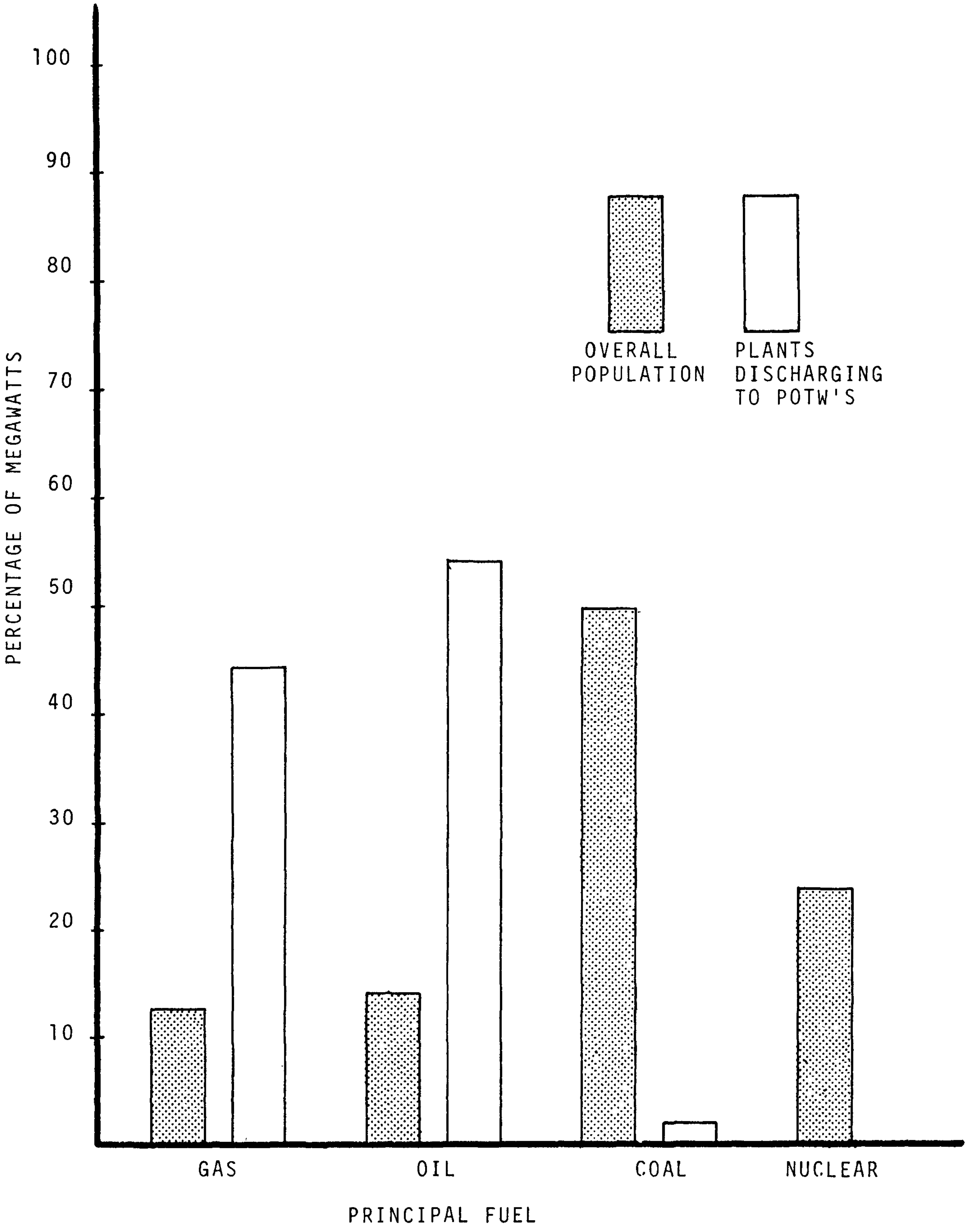


FIGURE III-2. Principal Fuel Use by Megawatts

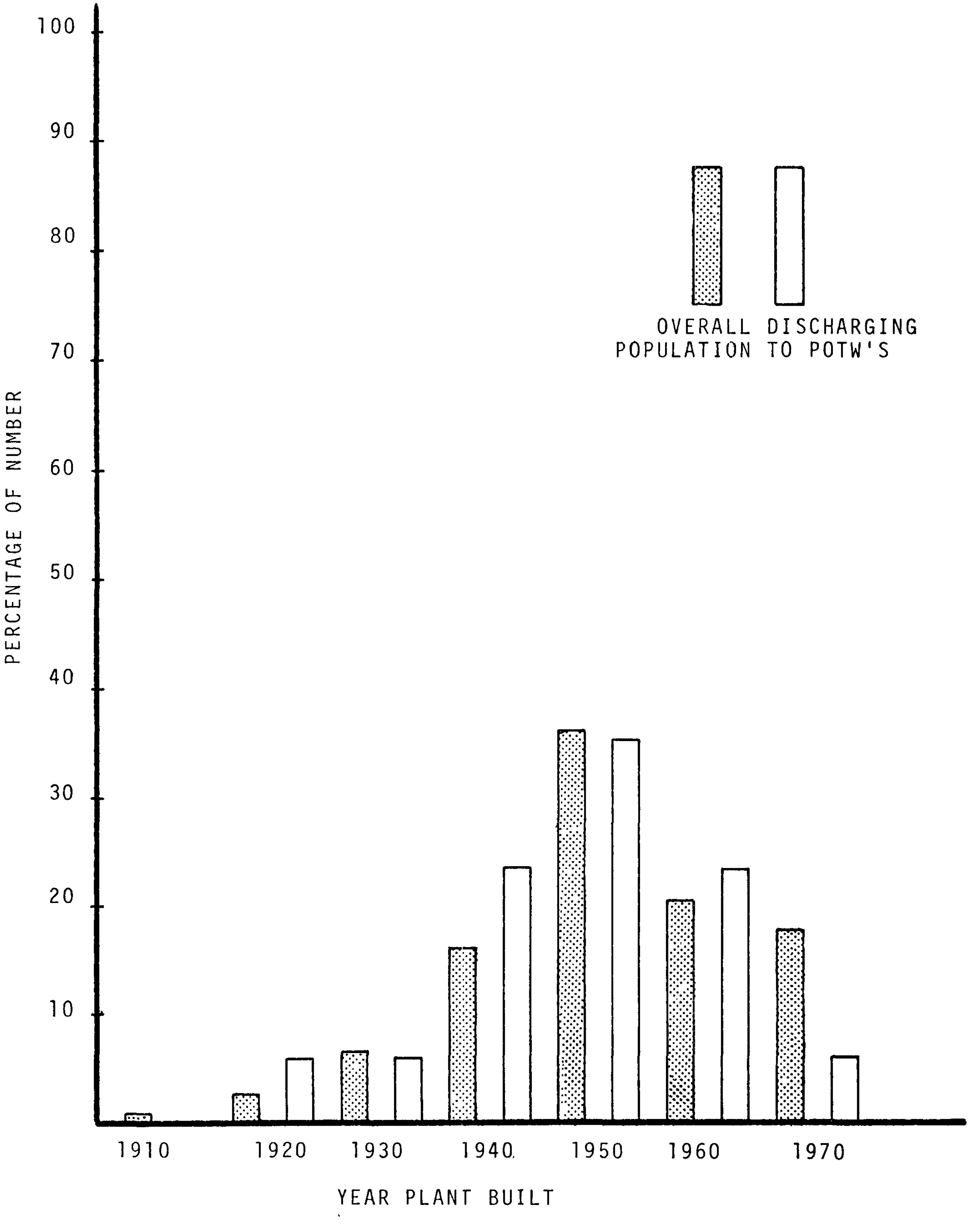


FIGURE III-3. Year of Construction by Number

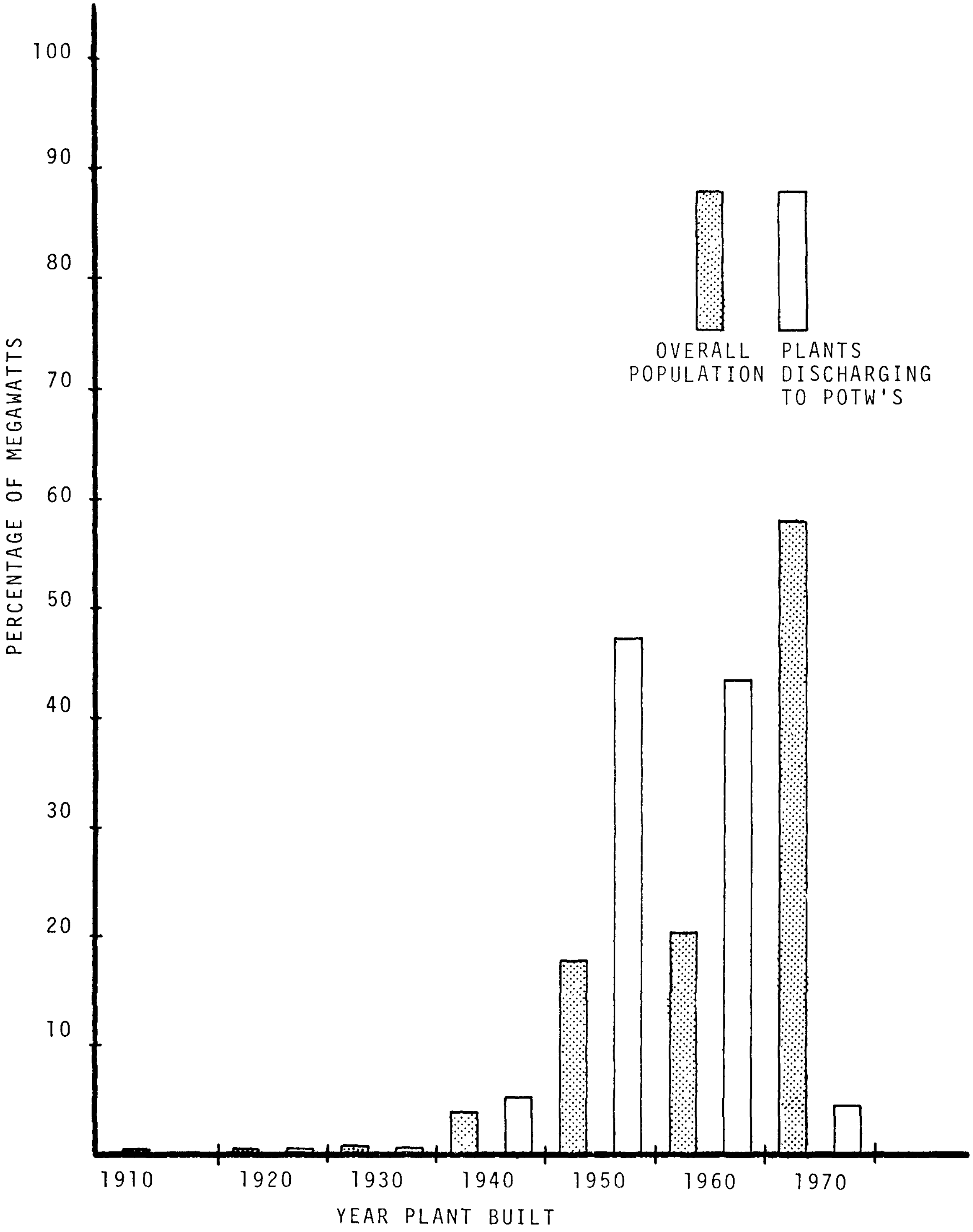


FIGURE III-4. Year of Construction by Megawatt combustion process, followed by steam generation to convert the heat first into mechanical energy and then to convert the mechanical energy into electrical energy. The maximum theoretical efficiency that can be obtained in converting heat to work is limited by the temperatures at which the heat can be absorbed by the steam and discarded to the environment. The upper temperature is limited by the temperature of the fuel bed and the structural strength and other aspects of the boiler. The lower temperature is ideally the ambient temperature of the environment, although for practical purposes the reject temperature must be set by design significantly above the highest anticipated ambient temperature. Within these temperatures, efficiencies are limited to about 40 percent regardless of any improvement to the machines employed. For any steam electric power generation scheme, therefore, a minimum of 60 percent of the energy contained in the fuel must be rejected to the environment as waste heat (14).

Fossil-fueled steam electric power plants produce electric energy in a four-stage process, shown in Figure III-5. The first operation consists of the burning of the fuel in a boiler and the conversion of water into steam by the heat of combustion. The second operation consists of the conversion of the high-temperature, high-pressure steam into mechanical energy in a steam turbine. The steam leaving the turbine is condensed to water, transferring heat to the cooling medium, which is normally water. The turbine output is conveyed mechanically to a generator, which converts the mechanical energy into electrical energy. The condensed steam is reintroduced into the boiler to complete the cycle.

The theoretical water-steam cycle employed in steam electric power plants is known as the Rankine cycle. Actual cycles in power plants only approach the performance of the Rankine cycle because of practical considerations. Thus, the heat absorption does not occur at a constant temperature, but consists of heating of the liquid to the boiling point, converting the liquid to vapor and superheating (heating above the saturation equilibrium temperature) the steam. Superheating is necessary to prevent excess condensation in the turbines and results in an increase in cycyle efficienty. Reheating, the raising of the temperature above saturation of the partially expanded steam, is used to obtain improvements in efficiency and again to prevent excess condensation. Preheating of condensate to near temperatures with waste heat, is also used for this purpose. Condensers cannot be designed to operate at theoretically optimum values because it would require infinitely larger equipment. All of these divergences from the optimum theoretical conditions cause a decrease in efficiency and an increase in the amount of heat rejected per unit of

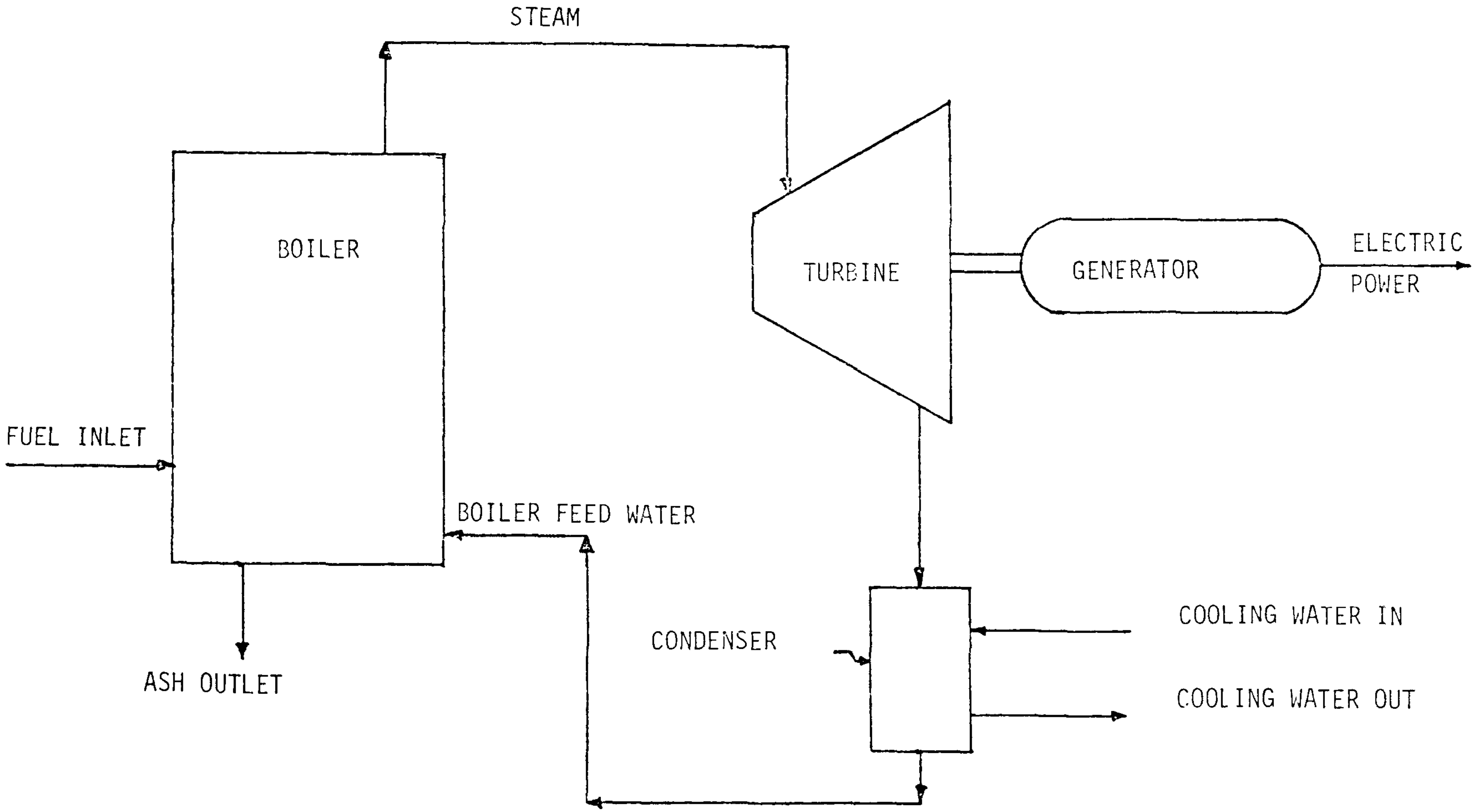


FIGURE III-5
Process Flow Diagram
Steam Electric Power Industry

production. As a result, only a few of the larger and newer plants approach even the efficiencies possible under the ideal Rankine cycle. Also, as a result of second law limitations, modifications of the steam cycle of an existing plant are not likely to result in significant reductions in heat rejection.

Publicly-Owned Treatment Works (POTW)

The POTW process is broken down into three basic treatment methods; primary, secondary, and tertiary. Primary treatment consists of the removal of coarse materials, settleable solids, oil and grease, floating material, and the reduction of biological oxygen demand. Most POTW employ secondary treatment which converts soluble and colloidal organic material into settleable flocculant material that can be removed by sedimentation. Secondary treatment which consists of biological treatment, is often enhanced by the addition of chemicals such as iron, aluminum salts, and polymeric flocculants. The use of tertiary treatment processes are still uncommon and include the removal of chemical constituents not affected by primary and secondary treatment. Tertiary treatment is intended to remove chemicals which promote algae growth and unwanted aquatic vegetation. A more detailed description of the POTW process can be found in Section V.

The POTW receiving wastewaters from steam electric plants vary in size and treatment process employed. Plant size is determined by human population and industrial waste load of the area served. Those contacted in this study ranged from 200,000 gpd to 350,000,000 gpd in size. Treatment methods are determined by flow, waste load pollutant constituents, economics, energy and removal requirements, and plant age. There are a large number of wastewater treatment processes in use whose application is related both to the characteristics of the waste and the degree of treatment required. These processes are shown in Figure III-6.

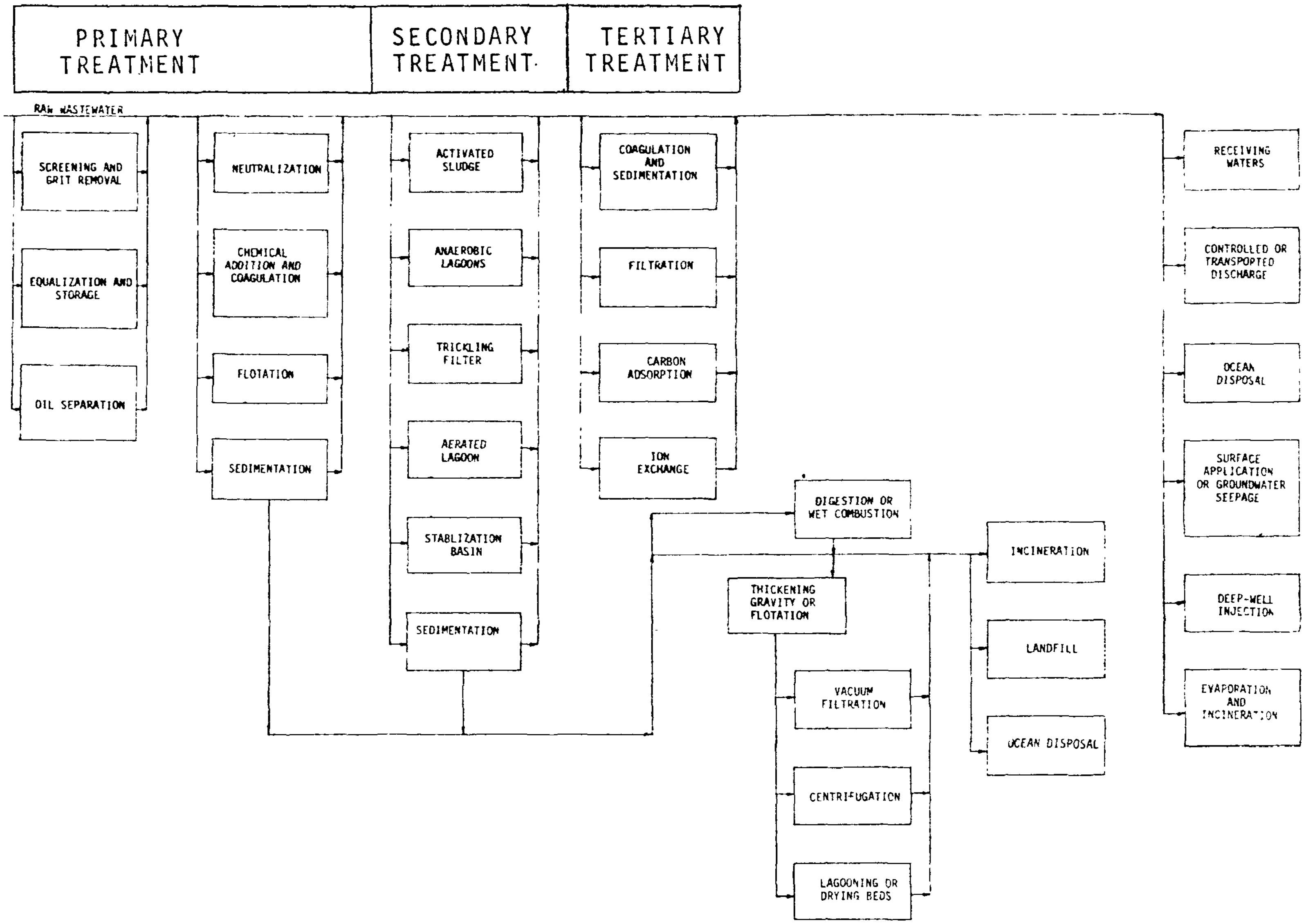


FIGURE III-6. Wastewater Treatment Sequence

SECTION IV

INDUSTRY CATEGORIZATION

INTRODUCTION

An evaluation of steam electric power industry stations discharging chemical wastes to publicly-owned treatment works (POTW) was necessary to determine whether categorization and subcategorization would be helpful in the preparation of effluent pretreatment standards for this industry. Subcategorization was based on distinguishing factors within groups of plants.

This method of subcategorization was also used and is discussed in detail in the "Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Steam Electric Power Generating Category" October 1974 (18).

Standards will be established for each waste source and can then be applied and utilized in the manner of a building block concept. In the case of combined waste streams the appropriate standards will be combined and weighted proportional to stream flow. The eight waste types are presented in Table IV-1.

The following were considered for industry categorization: age, size, fuel, geography, mode of operation, raw water quality, volume of water used, and pretreatment technology.

INDUSTRY CATEGORIZATION

The wastes of this industry have been divided according to the individual waste source. Marked differences in type and level of pollutants were observed in facilities with different fuel type, boiler and pretreatment practice. These differences were considered together with age, size, geography, mode of operation, and feed water hardness in the development of possible subcategorization.

FACTORS CONSIDERED

Age

Power plants discharging to the POTW tend to be older than surface water discharging plants. In steam electric power plants, individual generation units are often installed at different times over a number of years. Newer units tend to be thermally more efficient then older units and use less fuel per killowatt hour of electricity produced. Because of fuel economics newer units generally tend to be used for base load production while other units are employed as peaking and cyclic units. Increased fuel efficiency may reduce wastewater loads such as ash transport water, wet scrubber water, etc.

Size

Although the size of steam electric power plants discharging to POTW varies significantly, the basic process is common to all facilities. Plant size was found to have little affect on quantity of treated effluent. Plants discharging to sanitary sewers tend to be smaller than power plants discharging to surface water.

Fuel

Plants discharging to POTW were identified as burning all three major fossil fuels, coal, oil, and gas. In contrast to the entire population of steam electric plants in the U.S. the majority of plants contacted in this study use gas as fuel. Fuel-related wastes such as ash control transport water and coal pile drainage, can contribute to wastewater discharge. The presence of sulfur in the fuel may require scrubbers. Therefore, the affect of different fuels on certain processes and effluents is useful for subcategorization.

Geography

Usually, steam power plants that discharge to the POTW are located near or within municipal boundaries. Most of the plants contacted were, in fact, situated in downtown areas. Plants discharging to the sewers were located in nearly all geographical regions of the United States. It is noted that recent trends toward larger power generating stations, and the institution of mine-mouth coal fed plants, have resulted in increased rural plant construction and a reduced number of municipally-located plants.

TABLE IV-1

I. Condenser Cooling System
  A. Once-Through
  B. Recirculating

II. Boiler Water Pretreatment
  A. Clarification
  B. Softening
  C. Ion Exchange
  D. Evaporator
  E. Filtration
  F. Other Treatment

III. Boiler or PWR Steam Generator
  A. Blowdown

IV. Maintenance Cleaning
  A. Boiler or PWR Steam Generator Tubes
  B. Boiler Fireside
  C. Air Preheater
  D. Misc. Small Equipment
  E. Stack
  F. Cooling Tower Basin

V. Ash Handling
  A. Oil-Fired Plants
    1. fly ash
    2. bottom ash
  B. Coal-Fired Plants
    1. fly ash
    2. bottom ash

VI. Drainage
  A. Coal Pile
  B. Contaminated Floor and Yard Drains

VII. Air Pollution Control Devices
  A. SO_2 Removal

VIII. Miscellaneous Waste Streams
  A. Sanitary Wastes
  B. Plant Laboratory and Sampling Systems
  C. Intake Screen Backwash
  D. Closed Cooling Water Systems

Mode of Operation

Many of the plants discharging into POTW are peaking and cyclic stations. The type of pollutants generated from base load, peaking, and cycling facilities are similar. The quantity of effluent per unit of energy generated is expected to be greated for peaking facilitites. Some of the plants generate steam for sell and for electrical production.

Raw Water Quality

Hardness would indeed affect operation by increasing the frequency of regeneration of the deionizer or recharging the softener. The harder the raw water the more frequently the deionizer anion and cation must be regenerated and the hot lime and zeolite units have to be recharged. For cooling tower intake, poor water quality would reduce the concentration factor and thereby increase discharge flow and pollutant loading.

Volume of Water Used

Water use varies greatly even among plants of approximately the same size. For cooling water, flow is primarily effected by the efficiency of the boiler system and temperature across the condenser. For chemical wastewater, factors such as a good maintenance procedure and raw water quality are sometimes more important than the capacity of the plant. For water short areas, the cost of the water supply encourages water conservation. Volume of certain water streams, such as boiler blowdown, can be greatly affected by the amount of steam produced for sendout.

Pretreatment Technology

Of the plants discharging into POTW, many plants discharge all of their wastewater effluent to municipal sewer systems; others discharge only a portion. The extent of pretreatment varies widely from no pretreatment to integrated plants using systems such as equalization, neutralization, etc. None of the facilities visited or contacted have pretreatment facility equivalent to that required to achieve BPCTCA.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

INTRODUCTION

Specific water uses and the waterborne wastes involved in steam electric plants discharging into publicly-owned treatment works (POTW) are described in this section, along with other process waste materials. Process waters are characterized as raw waste loads from specific processes associated with the production of electricity. These are generallly expressed as grams per megawatt hour (MWH) of electricity generated. Water uses are given in terms of liters per MWH, or as liters per day and waterborne waste loads in mg/liter or grams per MWH. Based on available data, it does not appear that the quantity of pollutants discharged is directly proportional to electrical generation. Factors such as raw water quality, maintenance procedures, etc., can be just as influential in determining chemical loadings as electrical generation. The waste treatments used by both power plants and POTWs are described, and amounts and types of waterborne waste effluents after treatment are characterized.

PRINCIPLES OF OPERATION OF STEAM ELECTRIC POWER PLANT

In a steam electric power plant, thermal energy, produced by rapid chemical combustion or nuclear fission reaction, is first tranformed into high pressure, high temperature steam, and then to mechanical energy through expansion of the steam in a turbine. The process can be divided into four stages. The first operation consists of fuel combustion in the boiler furnace to produce high pressure, superheated steam. The steam is conveyed to a turbine where it is allowed to gradually expand and cool in the various turbine stages to convert the thermal energy into electrical energy via mechanical energy. In the third operation the steam exiting from the final stage of the turbine is condensed to water, transferring the heat to a cooling medium, which is normally water. Finally the condensed steam is reintroduced into a boiler by a pump to complete the cycle.

The power cycle components can be divided into three principal units:

- steam boiler
- steam turbine
- condenser

Each of the cycle components provides an energy transfer and transformation function necessary to convert the heat energy into useful work. The following are descriptions of these three units. A more extensive discussion on the principles of design and operation of steam electric power plants can be found elsewhere (14,16).

Boilers

All boilers use the same basic design, that is, they are large multi-tube heat exchangers surrounded by a furnace. The feedwater circulates within the tubes where it is heated, vaporized, and superheated producing steam to drive the steam turbine generators. Many different boiler arrangements are used. Oil and gas-fired boilers somewhat are simpler than coal-fired boilers because in most cases liquid and gaseous fuels do not require the conveyers, pulverizers, and ash collection equipment necessary in coal-fired boilers. The boiler structure may be either exposed or enclosed depending on local weather conditions, and is usually very large to accommodate the large tube surface areas required. Air heaters, economizers, and other sections of the boiler are used to extract the maximum amount of heat from the combustion gases before they are discharged to the environment. This serves to increase the boilers efficiency: the ratio of heat converted to steam to the heat input value of the burning fuels. Modern power boilers are able to achieve 85 to 90 percent efficiencies; the remaining 10 to 15 percent of the input heat value is discharged to the environment with the exhaust gases. This loss is referred to as the "stack loss." Figure V-1 shows a typical boiler for a coal fired furnace.

Steam Turbine

The steam turbine consists of alternate rows of nozzles and blades on wheels. Each row of nozzles and its associated row of blades is called a turbine stage. As the steam expands through the nozzles, the pressure decreases and the velocity and specific volume increase. When the steam comes in contact with the blades a part of the momentum (kinetic energy) is transferred to the blades. The turbine shaft and generator are caused to rotate and electricity is produced.

There are many different types of turbines and turbine arrangements in use. Most of the turbines are of the condensing type, discharging the steam from the last stage at below atmospheric pressure. The efficiency of a turbine is highly sensitive to the exhaust pressure (back pressure). Turbines designed for once-through cooling systems are generally operated at lower back pressures than that designed for closed cooling systems.

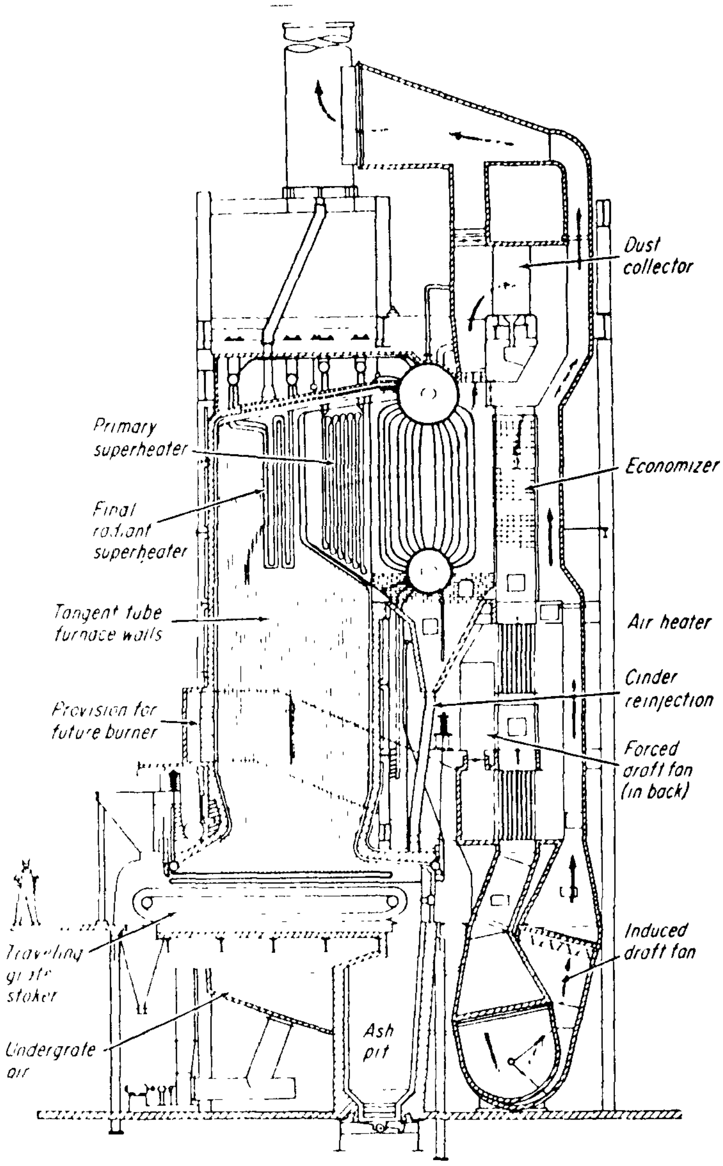


Figure V-1. Typical Boiler for Coal-Fired Furnaces

In most turbine arrangements a portion of the steam leaves the casing before the final stage. This type of turbine is referred to as extraction turbine. The extracted steam is used for feedwater heating purposes. In some turbines, a portion of the steam is extracted from intermediate stages, reheated in the boiler, and returned to the turbine or another turbine as a means of improving overall efficiency.

Steam Condensation

Steam leaving the final stage of the turbine is condensed into water in the condenser. This is essentially a very large shell and tube heat exchanger designed to withstand the high vacuums associated with modern steam turbine power cycles. Heat is transferred from the exhaust steam to an external cooling water system which may draw water from a surface or underground source, or from the cooling tower. There are two types of condensers; the single-pass and the two-pass condensers. If all the water flows through the condenser tubes in one direction, it is call a single-pass condenser. If the water passes through one half of the tubes in one direction and the other half in the opposite direction, it is referred to as a two-pass condenser. A single-pass condenser usually requires a larger water supply than a two-pass condenser and generally results in a lower temperature rise in the cooling water. Many condensers have divided water boxes so that half the condenser can be taken out of service for cleaning while the unit is kept running under reduced loads. Condensers are periodically cleaned mechanically as part of regular scheduled maintenance procedures. Some plants employ continuous on-line mechanical cleaning. Figure V-2 shows a typical single-pass condenser.

WATER USE AND WASTE CHARACTERIZATION BY CATEGORY

The results obtained on power plant wastes from visiting twenty-three plants and sampling eight do not differ substantially from those reported in the "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category" (14).

The majority of the water used in steam electric generating plants is for condenser cooling water. Lesser amounts are used for boiler makeup water, bearing cooling water, equipment cleaning, and other miscellaneous purposes. Figure V-3 shows a typical Steam Electric process diagram with wastewater sources.

Waste discharges can be classified under two categories: continuous discharges, and intermittent discharges. Wastes

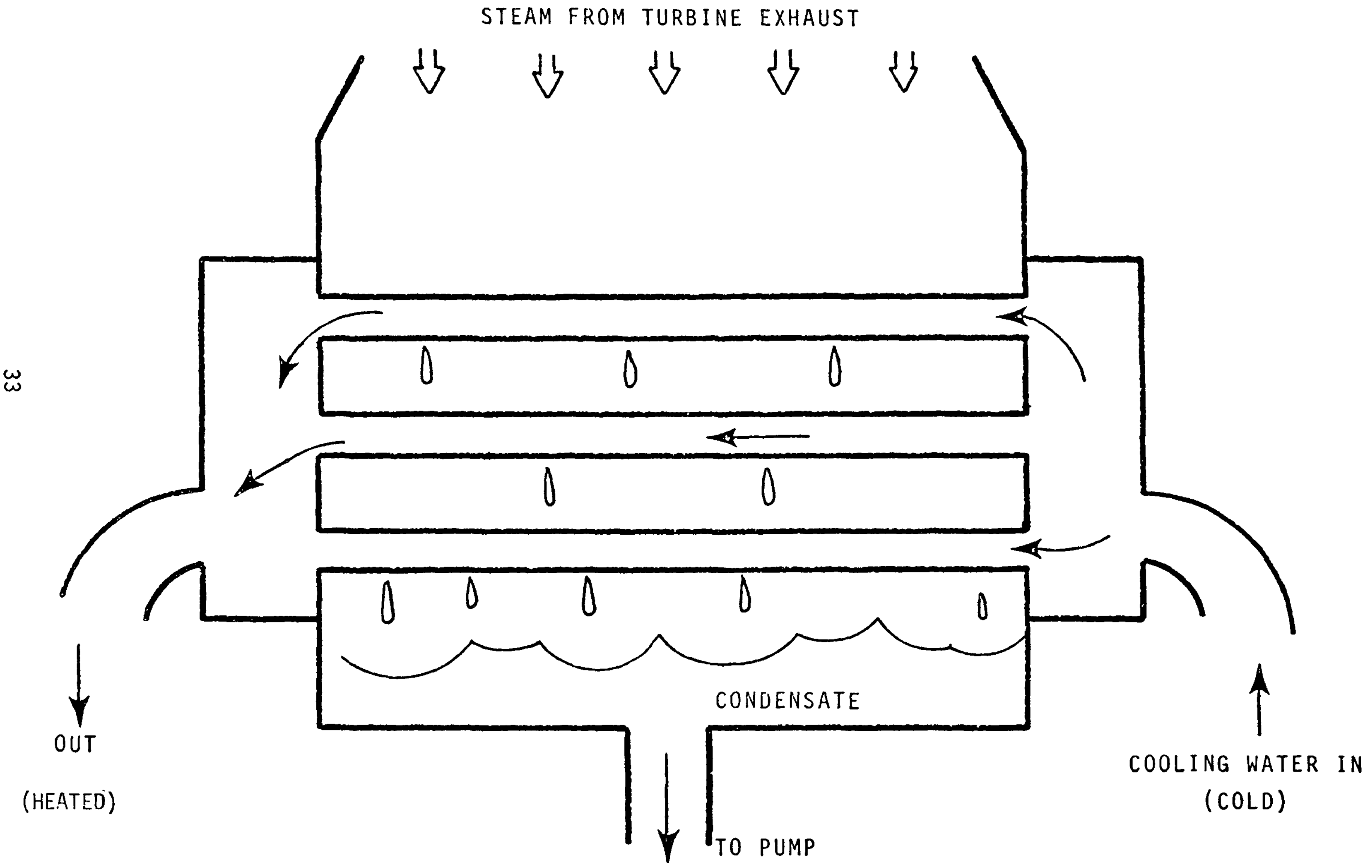


FIGURE V-2. Single-pass Condenser

are produced on a continuous basis from the following (if applicable): cooling water systems, ash handling systems, wet-scrubber air pollution control systems, and boiler blowdowns (some of the streams can be intermittant). Waste discharges are produced intermittently by boiler water treatment operations such as ion exchange, filtration, clarification, and evaporation. Intermittent discharges are also produced during miscellaneous equipment cleaning operations and from sanitary and laboratory wastes.

The following discussion is a categorization and description of water uses and waste discharges within typical generating plants. Some of the following has been summarized from Reference 14, which contains a more detailed discussion of water use and waste characterization. Data obtained from the site visits and sampling program are discussed below.

CONDENSER COOLING WATER

The condenser cooling systems can be classified as (1) once-through, or (2) recirculating. Of the twenty-three plants surveyed, seven use once-through, thirteen use recirculating, one plant is a hybrid, and two plants operate only at peak periods and are therefore not included in this section.

Once-Through Systems

In areas where large amounts of water are available from natural sources, the simplest method of condensing steam is to withdraw water from the source, pass it through a condenser, and discharge it back into the same source at a higher temperature. Biocides such as chlorine or hypochlorites are usually added to systems of this type to minimize biological growth within the condenser. Of the plants surveyed in this study, none were observed to discharge once-through cooling systems to POTW.

Recirculating Systems

Condenser cooling water can be recirculated within the plant. This is accomplished by providing some sort of artificial cooling device, such as a pond or a cooling tower, to cool the cooling water by evaporating a portion of it before recirculating it back to the condenser. Ponds are used only where large areas of inexpensive land are available, since a large plant may require over 1,000 acres of pond surface. Cooling towers may be either of the wet or dry types, and are used where sufficient land for ponds is unavailable or too expensive. Since all cooling devices (except dry cooling towers, which are rare) transfer the process waste heat to the atmosphere by evaporation.

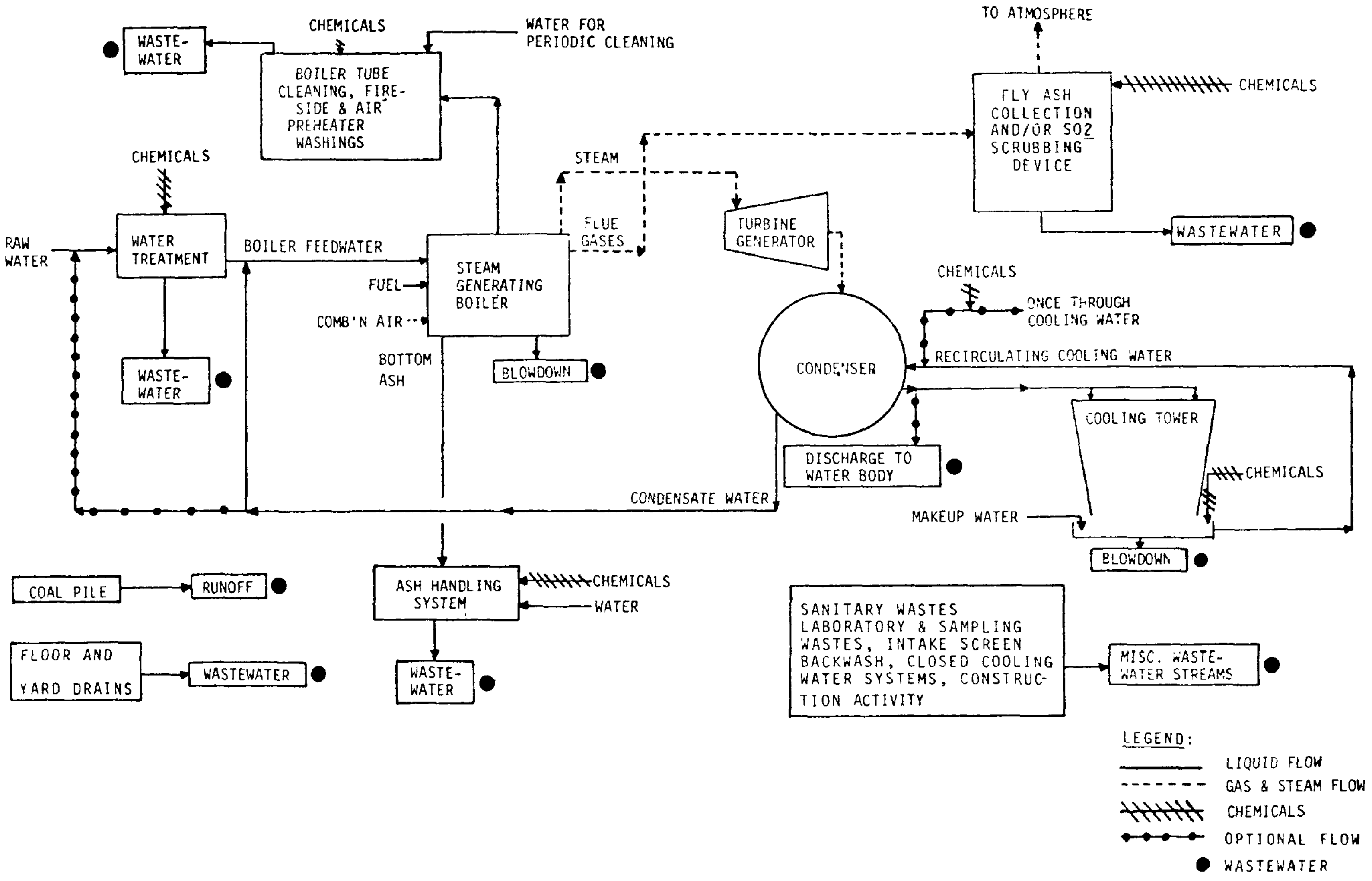


FIGURE V-3 - Fossil-Fueled Steam-Electric Power Plant - Typical Flow Diagram

Additional water must be added to the system to make up for these losses due to evaporation, drift and blowdown.

Various chemicals are added to recirculating cooling systems to prevent biological growth in cooling towers and to control scale accumulation and corrosion in condensers. These include biocides such as chlorine, hypochlorites, and organic chromates; corrosion inhibitors such as organic phosphates, sodium phosphate, chromates, and zinc salts; and fungicides.

Wastes that may be discharged to a POTW from recirculating cooling systems originate from cooling tower blowdown. Blowdown is the discharge from the cooling tower of a portion of water either constantly or intermittently to prevent the concentration buildup of salts that may form scale deposits within the condenser. This blowdown will contain calcium, magnesium, and sodium cations in combination with carbonate, bicarbonate, sulfate, and chloride anions. Additionally, various amounts of the conditioning chemicals will be present. Sulfuric acid is also used in closed cycle cooling systems.

The rate of blowdown can be estimated by the use of the following equation: (Ref. 1)

$$B = \frac{Ev - D(C-1)}{C-1}$$

where: B is the blowdown rate; Ev is evaporation rate; D is drift losses; and C is the cycles of concentration defined as the ratio of the concentration of a critical chemical species in the blowdown to that in the makeup water.

The evaporation rate (Ev) from cooling towers averages about 1.5 percent of the cooling water flow for every 10°C rise in cooling water temperature as the water passes through the condensers. The drift rate (D) for new cooling towers is about 0.005 percent of the cooling water flow for mechanical draft towers, and about 0.002 percent for natural draft towers (Reference 1). Cycles of concentration (C) is an expression of the buildup of any constitutent in the cooling water system from its original value in the makeup water. In practice, C is usually between 4 and 6. For very high quality makeup water, C may be as high as 15, and for very saline water, C may be as low as 1.2-1.5.

Figure V-4 shows typical once-through, and recirculating cooling system flow diagrams. Figures V-5 and V-6 show two types of wet cooling towers.

Water Use

Once-Through Systems. Seven of the twenty-three plants surveyed use a once-through cooling system to remove the waste heat from the process. The water usage in liters per MWH at the plant studied is given below:

Plant No.	Water Usage Liter/MWH
9369	9.33×10^{4}
7420	3.3×10^{4}
9163	1.18×10^{5}
6387	3.68×10^{5}
8356	2.57×10^{5}
6421	2.24×10^{5}
6294	8.28×10^{4}

A similar range of water use for once-through condenser cooling of 1×10^{5} to 3.5×10^{5} liters per MWH was reported elsewhere (14).

The water use data were plotted against power generation rate to determine the effect of that function on the quantity of water used. (See Appendix A). The results of the statistical analysis suggest that, based on the available data, there is at best a poor correlation between water use for once-through cooling system and generation rate for plants in this study. Although the overall trend suggests that the water use may decrease slightly with increasing generation rate, this is not substantiated by the statistical analysis of available data. One explanation for such phenomena is that cooling water pumps are in on-or-off modes. For a facility with two cooling water pumps, production would have to be less than half of the design capacity before the cooling water flow would decrease. For some facilities, the pumps are always kept in operation to lessen pump maintenance. Another explanation is the change in temperature across the condenser between stations.

Recirculating Systems. Thirteen of the 23 plants surveyed use a recirculating condenser cooling system to remove waste heat from the process. Waste heat is removed from the cooling water by means of evaporation and blowdown. Water usage in liters per MWH at the plants studied is given below:

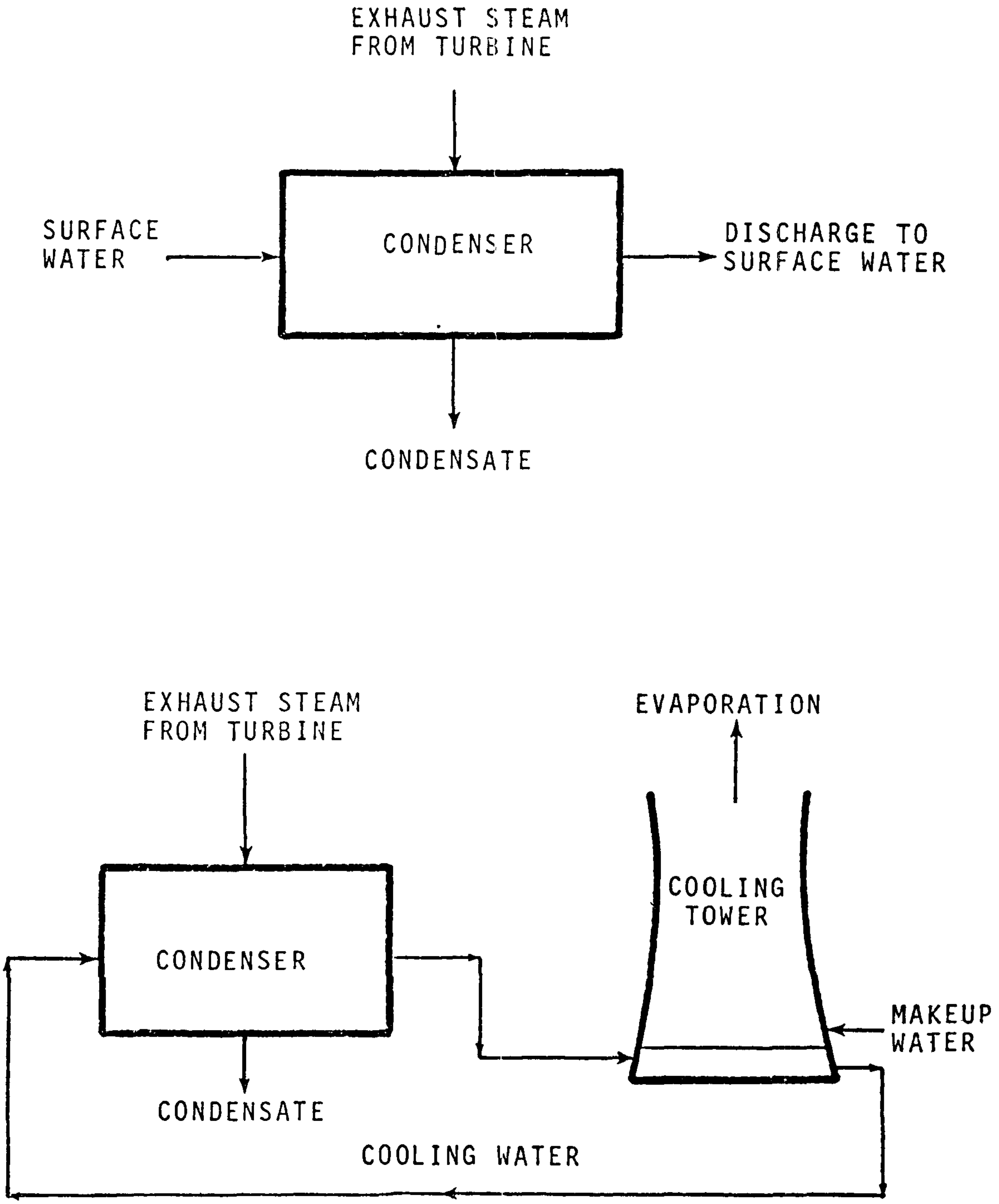


FIGURE V-4. Once-Through (top) and Recirculating (bottom) Cooling Systems

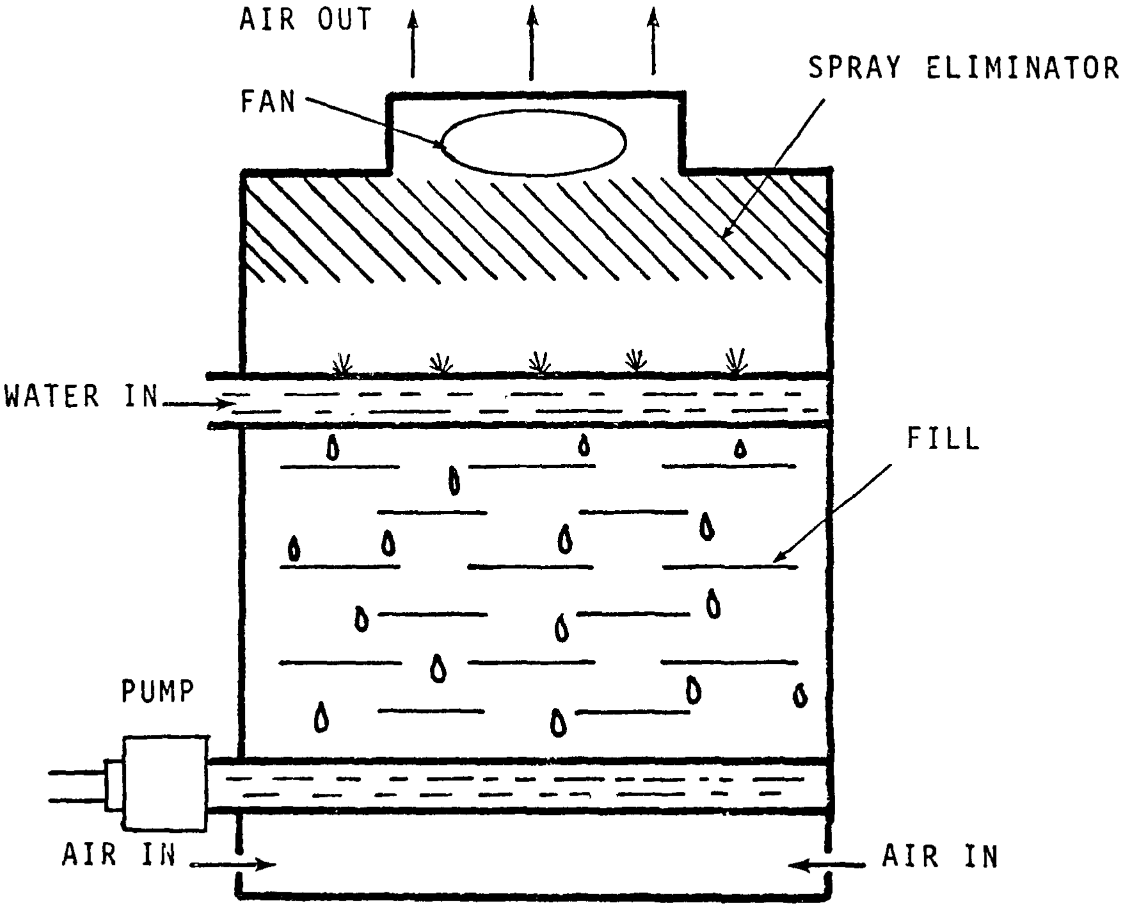


FIGURE V-5. Diagram of Wet Induced-Air Cooling Tower

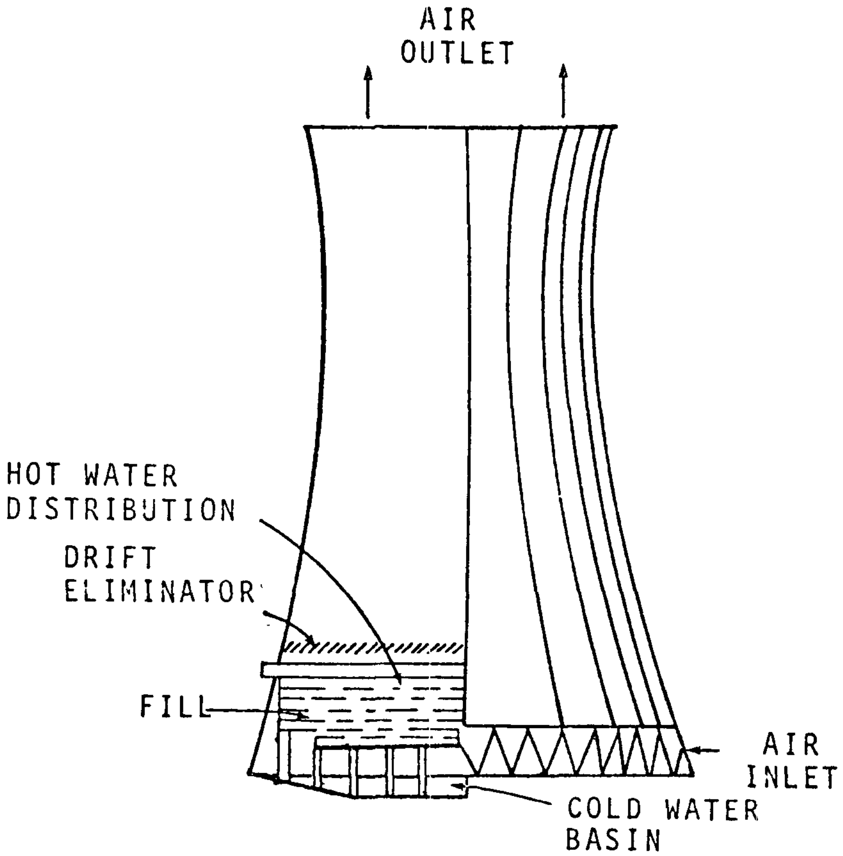


FIGURE V-6

Natural-Draft Wet Cooling Tower
(Counter-Flow)

Plant No.	Water Usage Liters/MWH
9600	1.64×10^{4}
9650	3.21×10^{3}
9369	1.80×10^{1}
9371	3.44×10^{3}
8816	2.14×10^{2}
9585	8.39×10^{2}
8696	5.6×10^{2}
8135	1.41×10^{4}
8392	1.76×10^{4}
6293	4.1×10^{3}
7308	1.8×10^{3}
8875	2.36×10^{3}
8231	2.53×10^{3}

The water usage data was plotted on log-log paper versus the production rate to determine the effect of the plant size on the quantity of water used. (See Appendix A). The results of the statistical analysis suggest that, based on the available data, there is no correlation at all between water use for recirculating condenser cooling and production rate. Although the overall trend suggests that the water use may increase slightly with production rate, this is not substantiated by the statistical analysis. An explanation for such phenomena is that the blowdown from a recirculating cooling system is not only a function of electrical generation capacity, intake water quality, geographical location, and governmental regulations, but also of other factors.

Raw Waste Load

The raw wastes from the recirculating condenser cooling process include:

- Chemical additives to control growth organisms such as algae, fungi, and slimes;
- Chemical additives to inhibit corrosion; and
- Concentrations of solids, metallic salts, and acidic and alkaline ions due to evaporative loss.

Initially, all of these wastes are waterborne, but some, such as suspended solids and metallic salts settle and must be removed from cooling tower basins periodically. Also, the settling of metallic salts cause scale formation on condenser tubes and may be removed occasionally usually with an acid solution. The remainder of the raw wastes are either removed from the wastewater by treatment technologies, or are discharged to the sewer systems.

Waterborne wastes are shown in Table V-1 for plants 8392, 8231, 9650, 8135, 8696, and 7308 from which data was obtained. The waterborne raw waste values indicate that the major components by weight in recirculating condenser cooling streams are dissolved and total solids, and chemical oxygen demand.

Wastewater Treatment

None of the plants using once-through condenser cooling systems discharge to POTW. Thirteen plants using recirculating condenser cooling systems discharge cooling tower blowdown to the POTW. None of the thirteen plants discharging recirculating condenser cooling wastewaters to POTW employed any treatment technologies. Wastes were discharged directly to the POTW without treatment.

Effluent Waste Loads

Information was not obtained on the composition of recirculating condenser cooling wastes after treatment since no plants performed any treatment before discharge to the POTW. Waterborne wastes present in the recirculating condenser cooling discharge to the POTW can be found in Table V-1.

WATER TREATMENT

To compensate for steam losses through leakage and boiler blowdown, additional water must be added to the boiler. Particularly in high-pressure boilers, this water must be of extremely high quality, and must undergo extensive treatment. If the water is taken from a municipal supply, treatment may consist of dual media filtration, reverse osmosis filtration, and demineralization. Older, low-pressure steam plants may treat boiler makeup water solely with evaporators. Some steam electric plants treat water by clarification and softening followed by demineralization. A more detailed description of those treatment schemes and their associated wastes follows.

Clarification is a process for removing suspended solids. After water is lime treated, clarification can be used to remove dissolved solids. Chemical coagulants such as alum, ferrous sulfate, ferric sulfate, sodium aluminate, and polyelectrolytes are added to the water to aid the agglomeration of dissolved impurities by adsorption, absorption, and sedimentation. The particles are allowed to settle, and the clarified water is drawn off and filtered. Softening is used in conjunction with clarification to precipitate calcium and magnesium. Clarification and softening wastes consist of sludges and filter washes.

Table V-1 . RAW WASTE FLOWS AND LOADINGS CONDENSER-COOLING SYSTEMS

PLANT NO.	8392		8135		8696		7308		8231		9650	
WASTEWATER SOURCE	Cooling Tower Blowdown		Cooling Tower Blowdown		Cooling Tower Blowdown		Cooling Tower Blowdown		Cooling Tower Blowdown		Cooling Tower Blowdown	
FLOW	L/Day 238455.0	L/MWH 745.81	L/Day 53959.0	L/MWH 321.51	L/Day 217788.9	L/MWH 18.03	L/Day (1)	L/MWH (1)	L/Day 580,365.4	L/MWH 555.37	L/DAY 1067370.0	L/MWH 1292.2
PARAMETER	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH
BOD_5	1.42	10.4	7.09	2.28	2.2	0.39	5.7	(1)	--------	------	--------	-------
Bromide (Bromate)	----	-----	-----	-----	----	----	----		--------	------	--------	-------
COD	9.8	7.3	102.91	33.14	25.2	0.45	64		--------	------	--------	-------
Chromium	4.9	3.65	0.02	------	<0.02	----	1.39		--------	------	0.07	0.09
Chromium^{+6}	3.3	2.46	0.004	0.001	0.012	0.0002	0.76		0.009	0.004	0.044	0.05
Copper	0.02	0.01	-----	------	0.35	0.002	0.7		0.12	0.06	0.05	0.06
Cyanide (Total)	0.02	0.01	0.014	0.005	<0.005	-----	0.025		--------	------	--------	-------
Iron	0.48	0.35	-----	------	0.32	0.005	1.63		0.15	0.08	0.29	0.37
Nickel	0.03	-----	------	------	<0.03	-----	0.04		0.03	------	0.03	-------
Oil and Grease	1.0	-----	7.43	2.39	2.4	0.043	1.9		1.0	------	4.0	5.16
Phosphate (Total)	3.25	2.43	------	-------	0.06	0.001	0.95		------	------	0.08	0.1
Total Dissolved Solids	886.0	660.78	943.45	303.74	2860	51.5	5111		------	------	--------	--------
Total Suspended Solids	2.9	2.16	3.89	1.25	33	0.59	59		8.3	4.0	16.0	20.67
Total Solids	889.0	660.8	946.73	304.85	2893	52.19	5170		-------	------	--------	--------
Surfactants	------	-------	-------	--------	-----	-----	-----		-------	------	--------	--------
Zinc	1.5	1.11	0.48	0.15	0.09	0.001	0.7		0.02	0.01	2.04	2.63

(1) Flow could not be measured.

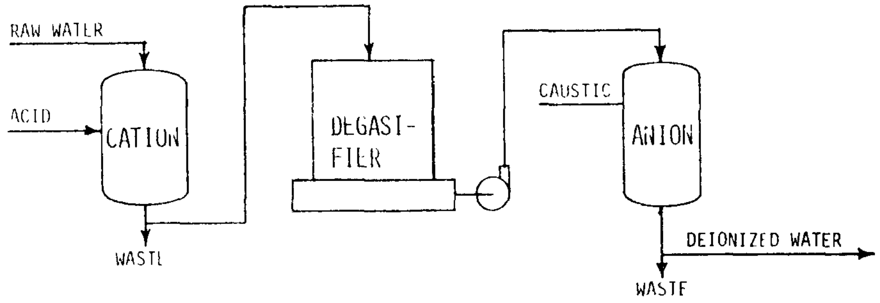
Clarifier sludge consists of either alum or iron, hydroxides plus suspended and dissolved impurities, softening sludge consist of calcium carbonate and suspended and dissolved impurities, and some softening sludges may also contain magnesium hydroxides. Filter washes contain suspended solids either carried over from the clarifier or contained naturally in the unclarified water.

Demineralization (ion exchange) is a process that removes mineral salts by adsorption on a resin. Two types of resins exist: cationic (for the removal of cations), and anionic (for the removal of anions). These resins may be used separately, (one following the other), or they may be combined in a mixed-bed (demineralizer). After a period of use, ion exchange resins become saturated with ions, and must be regenerated. Anionic resins are regenerated with sodium hydroxide solution followed by water rinse to remove excess sodium hydroxide. The regeneration waste will have a high pH and will contain the exchanged anions, which are: sulfate, chloride, nitrate, and phosphate. Cationic resins are regenerated with sulfuric acid, and the regeneration waste from those units will have a low pH and will contain calcium, magnesium, potassium, and sodium ions.

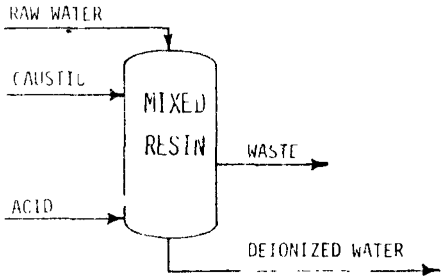
Evaporation is simply a distillation process for the removal of impurities. Evaporators usually consist of a horizontal vessel heated by a waste heat source, which is usually exhaust steam from the turbines. Steam from the evaporation of water in the vessel is drawn off and condensed in an external condenser. To prevent a concentration buildup of salts which contribute to scaling problems within the vessel, a portion of the water is drawn off as blowdown. This blowdown has a high pH, and contains the same chemicals present in the raw water feed, which have been concentrated by a factor of three to five. Calcium carbonate and calcium sulfate precipitates may also be present in the blowdown if present in the water feed in sufficiently high concentrations. Phosphate is sometimes added to the raw water feed to lessen the precipitation of calcium salts (14).

Reverse osmosis is a process used by some plants to remove dissolved salts. The technique consists of forcing water through a semipermeable membrane under a pressure greater than the osmotic pressure of the dissolved salts. The salts are concentrated on one side of the membrane and the purified water is collected on the other. The concentrated salt solution (brine) is discharged as a waste.

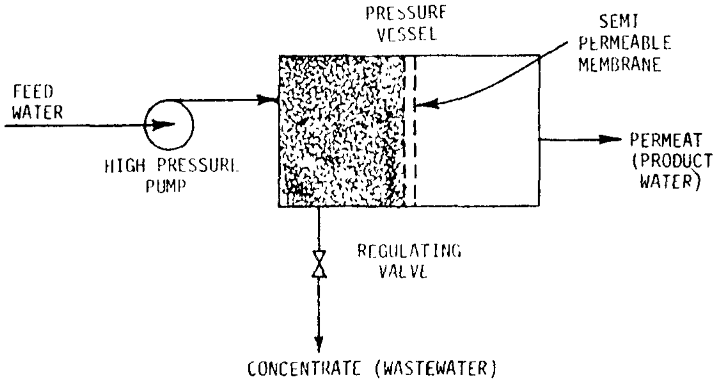
Chemical Additions. After treatment, various chemicals are added to the boiler makeup water. These include hydrazine or sodium sulfite (to remove dissolved oxygen), sodium



Two-Bed Ion Exchange Demineralizer With Degasifier

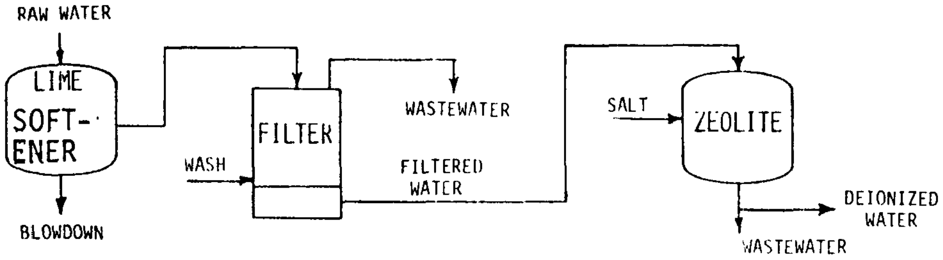


Mixed-Bed Ion Exchange Demineralizer

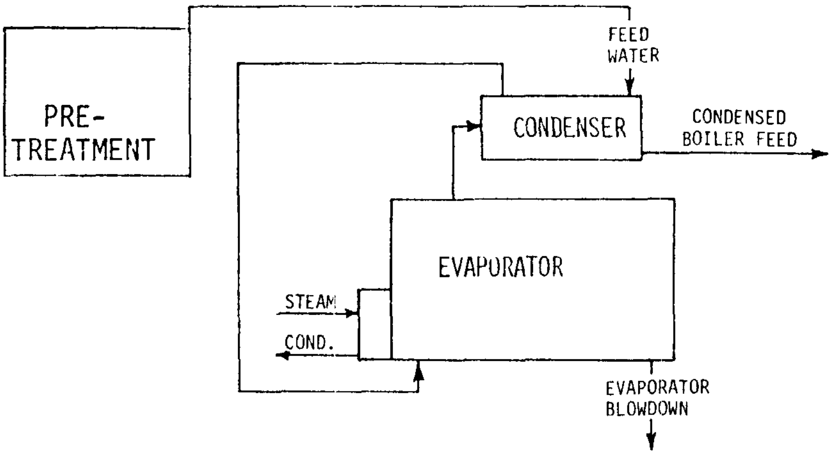


Reverse Osmosis Membrane Filter

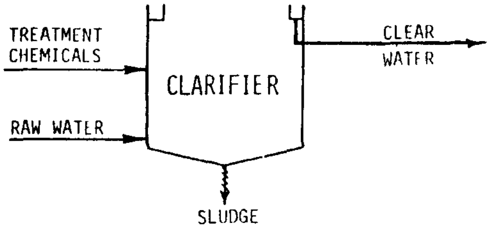
Figure V-7. Commonly Used Make-Up Water Treatment Methods



Lime Softening, Filtration & Sodium Zeolite Water Treatment Process



Evaporation Process



Clarification Process

FIGURE V-7. Commonly Used Water Treatment Methods (Continued) phosphate (to prevent scale formation by precipitating calcium and magnesium salts), and sodium hydroxide, ammonia, morpholine, or cyclohexylamine (to control pH).

Figure V-7 shows six (6) commonly used water treatment methods.

Water Use

Boiler Makeup Water. Sixteen of the twenty-three plants surveyed provided information on their boiler makeup water usage. The water use in liters per MWH at the plants studied is given below.

Plant No.	Water Usage Liters/MWH
9650	36.76
9369	79.56
9371	36.73
8816	29.93
9585	1.59×10^{2}
8696	4.15
8135	4.03×10^{1}
9163	1.32×10^{2}
6387	1.08×10^{3}
8356	1.78×10^{2}
8392	1.19×10^{3}
6293	6.81
7968	3.46×10^{2}
6421	4.58×10^{1}
6294	1.06×10^{2}
8231	5.43×10^{1}

The water usage data was plotted on log-log paper versus the production rate to determine the effect of the plant size on the quantity of water used. The results of the statistical analyses suggest that, based on the available data, there is a fair correlation between water use for boiler makeup and production rate. The overall trend appears to be a decrease in water usage with increasing production rate.

Demineralizer Regenerant Wastes. Thirteen of the twenty-three plants surveyed presented information on their demineralizer system regenerant water usage. The water usage in liters per MWH at the plants studied is given below:

Plant No.	Water Usage, Liters/MWH
	Regenerant
9650	65.75
9369	17.51

9371	27.55
9585	3.24x10^{2}
8696	4.56
9163	18.38
6387	13.46
8356	4.22x10^{2}
8392	7.1
6293	9.01
8875	11.35
6421	39.23
6294	5.69

The water usage data was plotted on log-log paper versus the production rate to determine the effect of plant size on the quantity of water used. The results of the statistical analysis suggest that, based on the available data, there is no correlation at all between water use for the regeneration of demineralizer system and the production rate. This result is not unexpected, since the regenerant water is a function of intake water quality, frequency of regneration, size of individual demineralizer plants, etc.

Raw Waste Load

The raw wastes from the water treatment process include:

- Mineral salts, suspended solids and other constituents removed from the raw water supply.
- Chemicals used by the water treatment units.

Of the twenty-three plants visited, three use hot lime-soda ash softening and zeolite ion exchange, two use hot lime-soda ash softening, filtration, and zeolite ion exchange, two use reverse osmosis and deionization, twelve use cation-anion ion exchange, one uses deionization and evaporation, one uses hot lime-soda ash softening, zeolite ion exchange and evaporation, and one uses deionization and evaporation.

Solid wastes are not generated in large quantitites during the regeneration process. The major source of solid wastes are calcium carbonate and magnesium hydroxide from the lime-soda ash softening processes. Waterborne wastes for plants in terms of grams per MWH are given in Table V-2.

Wastewater Treatment

Fifteen plants discharge water treatment waste streams to POTW. Five of these plants practice some type of pretreatment before discharge. Plant 6293 uses lime settling; plant 9369 uses equalization and neutralization; plant 7308 uses equalization, neutralization, and oil skimming; plant 8696 uses equalization, settling, and oil skimming and plant 7116 uses equalization, neutralization, and settling.

Effluent Waste Loads

Table V-3 shows the composition of pretreated wastewater discharge to the POTW in terms of concentration and waste loads for plant 6293.

BOILER BLOWDOWN

To prevent the accumulation of calcium and magnesium salts on the internal boiler surfaces, phosphates are usually added to precipitate the salts. The precipitate is removed continuously or intermittently by withdrawing a portion of the boiler water as blowdown. Blowdown wastes have a high pH, may, depending on boiler pressure contain high dissolved solids concentration. Blowdown from boilers treated with phosphate may contain hydroxide alkalinity and will contain phosphate, and blowdown from boilers treated with hydrazine will contain ammonia and depending on boiler pressure, may also contain sulfite.

Raw Waste Load

The raw wastes from boiler blowdown contain:

- Products of chemical additives to remove oxygen;
- Chemical additives to prevent scale or inhibit corrosion; and
- Concentrations of dissolved solids and other constitutents present in the boiler feedwater.

Boiler blowdown does not generate large quantities of solid waste. Sludge, consists principally of precipitated iron, calcium and magnesium salts, where phsophate treatment is used and is maintained in a fluid form and removed by the blowdown. Blowdown may contain ammonia when treated with hydrazine.

Waterborne wastes for two plants in terms of grams per MWH are given in Table V-4.

The waterborne raw waste values indicate that the major components by weight in boiler blowdown streams are dissolved solids, chemical oxygen demand, and total phosphates.

Wastewater Treatment

Table V-2 RAW WASTE FLOWS AND LOADINGS - WATER TREATMENT

PLANT NO.	6293		8135		8392		6387		6387		6387		8231		8231		9650	
WASTEWATER SOURCE	Lime Softener Blowdown		Demineralizer Regeneration		Demineralizer Regeneration		Lime Softener Blowdown		Lime Softener Blowdown		Evaporator Blowdown		Demineralizer Regeneration		Demineralizer Backwash		Demineralizer Regeneration	
FLOW	L/Day 16351.2	L/MWH 68.13	L/Day 4277.05	L/MWH 3.05	L/Day (1)	L/MWH (1)	L/Day 17168.7	L/MWH 47.69	L/Day 7570	L/MWH 252 33	L/Day 40878	L/MWH 113.55	L/Day 22710	L/MWH 21.73	L/Day 2573.8	L/MWH 2,46	L/Day 5105 75	L/MWH 61 8
PARAMETER	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH
BOD$_5$	48.0	3.27	1.0	0.003	1.0		1.8	0.08	10.4	2.62	15.2	1.72	-----	-----	-----	-----	------	------
Bromide (Bromate)	----	-----	1.49	0.004	1.02		----	-----					-----	-----	-----	-----	------	------
COD	37.2	2.53	9 8	0 03	2 0		200	9 53	561	141.55	76.0	8 62	-----	-----	-----	-----	------	------
Chromium	0.09	0.006	0.02	-----	0.02		0.11	0.005	0.1	0.02	0.02		0.07	0.001	0.02	-----	0.2	0 01
Chromium+6	0.006		0.002	-----	0 005		0.004		0.007	0.001	0.005	0.0005	0.006	0.0001	0.005	-----	0 01	0 0006
Copper	0.06	0.004	0.02	-----	0.02		0.15	0.007	0.12	0.03	0.02	0 002	0.02	------	0.02	-----	0.59	0 03
Cyanide (Total)	0.005		0.005	-----	0.005		0.014	0.0006	0.005	0.0011	0.006	0.0006	-----	------	-----	------	------	-------
Iron	9.0	0.6	0.02	-----	0 07		10.4	0.49	0.44	0.11	0.38	0.043	1.26	0.02	0.03	------	9.46	0 52
Nickel	0.07	0.004	0.03	-----	0.03		0.09	0.004	0.25	0.06	0.03		0.14	0 003	0 03	------	0.2	0 01
Oil and Grease	1.0		1.0	-----	1.0		1.0		1.0		1.0		13.2	0 28	9 2	0.02	1 0	-------
Phosphate (Total)	---	----	----	0.05	0.05						6.20	0.7	-----	-----	------	------	------	-------
Total Dissolved Solids	188	12.8	0.16	174	174		1004	47.88	22980	5798.6	2228	252.9	-----	-----	------	------	------	-------
Total Suspended Solids	1780	121.27	----	1.0	1.0		9440	450.2	44	11.1	93	105.6	31	0.63	6.8	0.016	16.7	1.03
Total Solids	1968	134.08	0.16	174	174		10444	98.08	23024	5809.7	2321	263.5	-----	-----	------	------	--------	-------
Surfactants	0.010	0.001	----	0.011	0.011								-----	-----	0.38	0.0009	--------	------
Zinc	0.12	0.008	----	0.02	0.02		0.32	0.015	0.09	0.02	0.11	0.01	0.06	0.001	0.01	------	0.21	0.01

(1) Flow could not be measured.

Table V-2. RAW WASTE FLOWS AND LOADINGS - WATER TREATMENT (CONTINUED)

PLANT NO.	8696		7308		7308	
WASTEWATER SOURCE	Cation Demineralizer Regeneration		Evaporator Blowdown		Zeolite Softener Back-Wash	
FLOW	L/Day	L/MWH	L/Day	L/MWH	L/Day	L/MWH
	11355(2)	0.94	(1)	(1)	4920.5(2)	0.29
PARAMETER	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH
BOD$_5$	6.0	0.005	5.16	(1)	27	0.008
Bromide (Bromate)	0.03	0.00002	----		0.07	Neg
COD	13.6	0.012	20.8		384	0.11
Chromium (Total)	0.07	0.00006	0.08		<0.02	-----
Chromium^{+6}	0.008	Neg.	0.036		0.016	Neg
Copper	1.3	0.001	2.61		0.13	Neg
Cyanide (Total)	<0.005		0.028		<0.005	-----
Iron	1.02	0.009	0.22		<0.57	-----
Nickel	<0.03		<0.03		0.20	0.00005
Oil and Grease	<1.0		1.9		1.4	0.0004
Phosphate (Total)	14.0	0.013	12.6		0.5	0.0001
Total Dissolved Solids	3960	3.72	2532.66		28066	8.21
Total Suspended Solids	30	0.03	14.5		18.4	0.005
Total Solids	3990	3.75	2547.16		28084.4	8.22
Surfactants	<0.01				0.021	Neg
Zinc	0.03	0.00002	0.44		0.08	0.00002

(1) Flow could not be measured
(2) Discharges 1 hour per day

Table V-3. EFFLUENT FLOWS AND LOADINGS - WATER TREATMENT

PLANT NO.	6293		8696		8237	
WASTEWATER SOURCE	Lime Softener Effluent		Diluted Demineralizer		Holding Tank Effluent	
FLOW	L/Day 16351.2	L/MWH 68.13	L/Day 54504	L/MWH 4.57	L/Day 15518.5	L/MWH 14.85
PARAMETER	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH
BOD_5	1.5	0.1	34.0	0.15	-------	------
Bromide (Bromate)	-----	-----	----	-----	-------	------
COD	5.9	0.4	81.0	0.36	-------	------
Chromium	0.02	0.001	0.05	0.002	0.05	0.0007
$Chromium^{+6}$	0.026	0.001	<0.005	-------	0.007	0.0001
Copper	0.02	0.001	0.88	0.004	0.02	------
Cyanide (Total)	0.005	-----	<0.005	-------	-------	------
Iron	1.23	0.08	3.0	0.01	0.85	0.020
Nickel	0.03	-----	<0.03	--------	0.09	0.001
Oil and Grease	1.0	-----	1.80	0.008	9.36	0.13
Phosphate (Total)	-------	------	----	--------	-------	-------
Total Dissolved Solids	152.0	10.35	954	4.30	-------	-------
Total Suspended Solids	245.0	16.69	219	0.98	25.02	0.35
Total Solids	397.0	27.04	1173	5.28	-------	-------
Surfactants	0.011	0.0001	------	-------	-------	-------
Zinc	0.2	0.0001	0.18	0.0008	0.04	0.0005

Thirteen plants discharge boiler blowdown to POTW, of which, three practice some type of pretreatment. Plant 9369 uses equalization and neutralization, plant 7116 uses equalization, neutralization and settling and plant 7308 uses equalization, neutralization and oil skimming.

Effluent Waste Loads

Although recovery of the blowdown is not practiced in most cases, this option should be considered since the blowdown water is almost always of better quality than the make-up water.

Information was not available on treated waste streams from boiler blowdown.

MAINTENANCE CLEANING

Boiler Tubes. Boiler tubes must be cleaned occasionally to remove accumulations of scale. A multitude of cleaning mixtures are used to accomplish this purpose. These include: alkaline cleaning mixtures with oxidizing agents for copper removal, acid cleaning mixtures, alkaline chelating rinses, organic solvents, and proprietary solvents. Wastes from these cleaning operations will contain iron, copper, zinc, nickel, chromium, hardness, and phosphates. In addition to these constituents, wastes from alkaline cleaning mixtures will contain ammonium ions, oxidizing agents, and high alkalinity; wastes from acid cleaning mixtures will contain fluorides, high acidity, and organic compounds; wastes from alkaline chelating rinses will contain high alkalinity and organic compounds; and wastes from most proprietary processes will be alkaline and will contain organic and ammonium compounds.

Boiler Fireside Cleaning. The fireside surface of boiler tubes collects airborne dust, fuel ash, and corrosion products. These materials are removed from time to time with high-pressure hoses. Alkaline chemicals may be used for safety and neutralization.

Wastes from this operation will be more or less acidic depending on the sulfur content of the fuel, and will contain hardness, suspended solids, iron, nickel, zinc, and other metals.

Air Preheater Cleaning. Air preheaters are used to heat ambient air that is used for combustion, and collect soot and fly ash. High-pressure hoses are used to remove these materials. The wastes from this operation will be more or less acidic, depending on the sulfur content of the fuel, and will contain suspended solids, magnesium salts, iron,

Table V-4. RAW WASTE FLOWS AND LOADINGS - BOILER BLOWDOWN

PLANT NO.	6293		8392		8231		9650	
WASTEWATER SOURCE	Boiler Blowdown		Boiler Blowdown		Boiler Blowdown		Boiler Blowdown	
FLOW	L/DAY 17030.4	L/MWH 70.96	L/DAY 1665.4	L/MWH 5.20	L/DAY 5715	L/MWH 5.47	L/DAY (1)	L/MWH (1)
PARAMETER	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH
BOD_5	11.7	0.83	10.8	0.06	----	------	-----	-----
Bromide (Bromate)	----	------	-----	----	----	------	------	-----
COD	157.0	11.1	2.0	----	-----	------	------	-----
Chromium (Total)	0.02	-------	0.02	0.0001	0.02	------	0.02	-----
$Chromium^{+6}$	0.007	0.0001	0.009	Neg.	0.005	------	0.005	-----
Copper	0.19	0.01	0.06	0.0003	0.02	------	0.02	-----
Cyanide (Total)	0.005	-------	0.014	Neg.	-----	------	------	------
Iron	1.4	0.1	0.08	0.0004	0.03	------	0.03	------
Nickel	0.03	------	0.03	------	0.03	------	0.03	------
Oil and Grease	2.2	0.15	1.0	------	14.8	0.08	5.3	------
Phosphate (Total)	18.7	1.32	19.8	0.1	0.05	------	0.05	------
Total Dissolved Solids	1405.0	99.7	118.0	0.61	-----	------	-----	------
Total Suspended Solids	2.7	0.19	6.9	0.036	31	0.17	8.3	------
Total Solids	1407.7	99.9	125.0	0.65	-----	-------	-----	------
Surfactants	------	-----	-----	------	-----	-------	------	------
Zinc	0.05	0.003	0.02	0.0001	0.01	-------	0.02	Neg.

(1) Flow could not be measured.

(2) pH values for plants: #6293=12.0, #8392=10.6, #8231=9.0, #9650=9.5

copper, nickel, and chromium. Vanadium may also be present if the plant is oil-fired.

Stack Cleaning. High pressure water is used to clean fly ash and soot from stacks. The frequency that this cleaning is required is dictated by the fossil fuel used. Wastes from this operation may contain suspended solids, metals, oil, and high or low pH values.

Cooling Tower Basin Cleaning. Deposits of carbonates on the bottoms of cooling towers and growth of algae on cooling towers are removed occasionally with water. The wastes contain suspended solids as a primary pollutant.

Miscellaneous Small Equipment. Occasional cleaning of plant equipment such as condensate coolers, hydrogen coolers, air compressor coolers, and stator oil coolers is performed. Detergents, wetting agents, and hydrochloric acid are often used during cleaning. Wastes from these operations will contain suspended solids, metals, oil, and low or high pH.

Raw Waste Load

The raw wastes from maintenance cleaning consist of the cleaning solution and the material removed from the equipment. Boiler fireside, air preheater, and boiler tube cleaning account for most of the wastewater generated in maintenance cleaning. No plants were performing maintenance cleaning during the time of our visitation and sampling.

Typical waterborne wastes are shown in Table V-5 for wastewaters from air prehater, boiler fireside, and tube cleaning. This information was obtained from Reference 14. Information was not available on cooling tower basin and stack cleaning wastewaters.

The major components by weight in the three cleaning waste streams are dissolved solids, hardness, metals, chlorides and sulfates.

Water Use

At infrequent intervals, certain power plants components such as condensate coolers, oil coolers, compressors, boilers, etc., are chemically cleaned with a solution of hydrochloric acid, or a detergent. Typical flow rates are summarized below.

Waste Stream	Waste Flow or Volume	Frequency	Typical Flow or Volume
Maintenance Cleaning			

Boiler Tubes	3-5 Boiler Volumes	Once/7 Months-once/100 mos.	1 boiler per 1-2 hours
Boiler Fire-side	24-720x10^3gal	2-8/yr	300,000 Gal
Air Preheater	43-600x10^3gal	4-12/yr	200,000 Gal
Misc. Small Equipment	No Date	-----------	-----------
Stack	No Data	-----------	-----------
Cooling Tower Basin	No Data	-----------	-----------

Wastewater Treatment

Plant 7308 discharges maintenance cleaning wastewater to a POTW through an industrial wastewater collection system and this was the only plant surveyed which disposed of cleaning wastewaters in this way.

Effluent Waste Loads

Information was not obtained on the composition of maintenance cleaning wastes after treatment.

ASH-HANDLING SYSTEMS

One of the products of the combustion of coal and oil in electric utilities is ash. Ash which falls to the bottom of the furnace is called bottom ash; ash which leaves the furnace with the flue gas is called fly ash. Fly ash is usually collected from coal-fired units with electrostatic precipitators and from large oil-fired units with cyclones. The function of ash-handling systems is to remove accumulated bottom ash and fly ash.

Two types of ash-handling systems exist: dry systems and wet systems. Dry systems use a mechanical conveyance devices for the transport of ash and are not a source of liquid wastes. Wet systems use water for the transport of ash, and in many cases, discharging it into a settling pond or basin.

Wet systems are either of the open type or the closed type. Open systems discharge supernatant from the settling basin into either a receiving water or a POTW. Closed streams recycle the supernatent back to the ash-transporting sluice for reuse. Figure V-8 shows a flow diagram for recirculating bottom ash system. Periods of extended

Table V-5. RAW WASTE FLOWS AND LOADINGS - MAINTENANCE CLEANING

No. of Plants	7 plants	2 plants	7 plants
Wastewater Source	Air Preheater	Boiler Fireside	Boiler Tubes
Cleaning Frequency (#/yr)	4-12	2-8	0-2
Flow (1000 liter)	163-2,271	91-2,725	568-18,622
Parameter (Kg)	Kg	Kg	Kg
BOD_5	0-6.82	0	----------
Bromide (Bromate)	--------	---------	----------
COD	2.6-15.9	8.63-515.00	0.45-19,387
Chromium (Total)	0.21-26.88	0.01-0.45	0.21-10,524
$Chromium^{+6}$	----------	--------	----------
Copper	0-2.02	0-0.11	0.06-931,185
Cyanide (Total)	----------	----------	-----------
Iron	0.97-3862	13.63-408.90	0.51-595.96
Nickel	8.14-170.38	0-13.63	42,592-133,826
Oil and Grease	----------	----------	------------
Phosphate (Total)	0.02-2.66	0.12-5.04	0.02-3.48
Total Dissolved Solids	1,448-20,096	1,363-15,948	111.11-43,598
Total Suspended Solids	217-4,898	54.07-1,736	0-1,590
Total Solids	1,188-29,744	1,817-18,551	111.11-48,868
Surfactants	----------	------------	------------
Zinc	0.13-11.36	0.91-13.04	0.35-391,098

rainfall may cause problems with closed systems, since some water may have to be withdrawn from the settling basin and discharged. Similarly, extended periods of dryness may evaporate excessive amounts of water from the settling basin, requiring the addition of supplementary water to the system.

Ash pond effluents from coal-fired plants contain a wide variety of constitents whose concentrations can vary widely depending on the particular coal used. Generally, the overflows contain high levels of dissolved solids, suspended solids, hardness, sulfate, sodium, magnesium, chloride, and alkalinity. Metals originally present in the coal may also be present. (14)

Ash is produced in oil-fired plants in very small quanitities. It has been found that oil ash does not settle as well as coal ash. In some utilities, the oil fly ash is recycled into the furnace, increasing efficiency and reducing the disposal problem. Ash pond overflows from oil-fired plants have some of the same characteristics as those from coalfired plants, and may additionally contain high concentrations of vanadium.

Table V-6 contains an itemization of the types of ash handling systems used by the plants that were visited.

Water Use

Of the twenty-three plants visited in this study, only four used water to convey fly and bottom ash to ash ponds; the remaining plants use dry ash transport systems. Of the four plants utilizing wet systems, all were coal-fired. Plant 9163 uses 2.65x10^{2} liters per MWH, the only plant using water for fly ash transport. The other three plants 6387, 8356, and 6294, respectively use 43.09, 3.61x10^{2} and 11.39 liters per MWH for bottom ash transport.

Raw Waste Load

Oil-Fired Plants. Fuel oils contain only about one percent of the amount of ash commonly found in coal, consequently, ash disposal problems from oil-fired plants are significantly less.

Fly Ash. Many of the oil-fired plants visited used mechanical cyclones to remove fly ash from the flue gases. A dry system is usually used to remove the collected ash. In other plants, no fly ash collection system is necessary because of the low ash content of the oil used. In these plants, most of the ash in the flue gases collects on the interior surfaces of the boiler and is removed by high

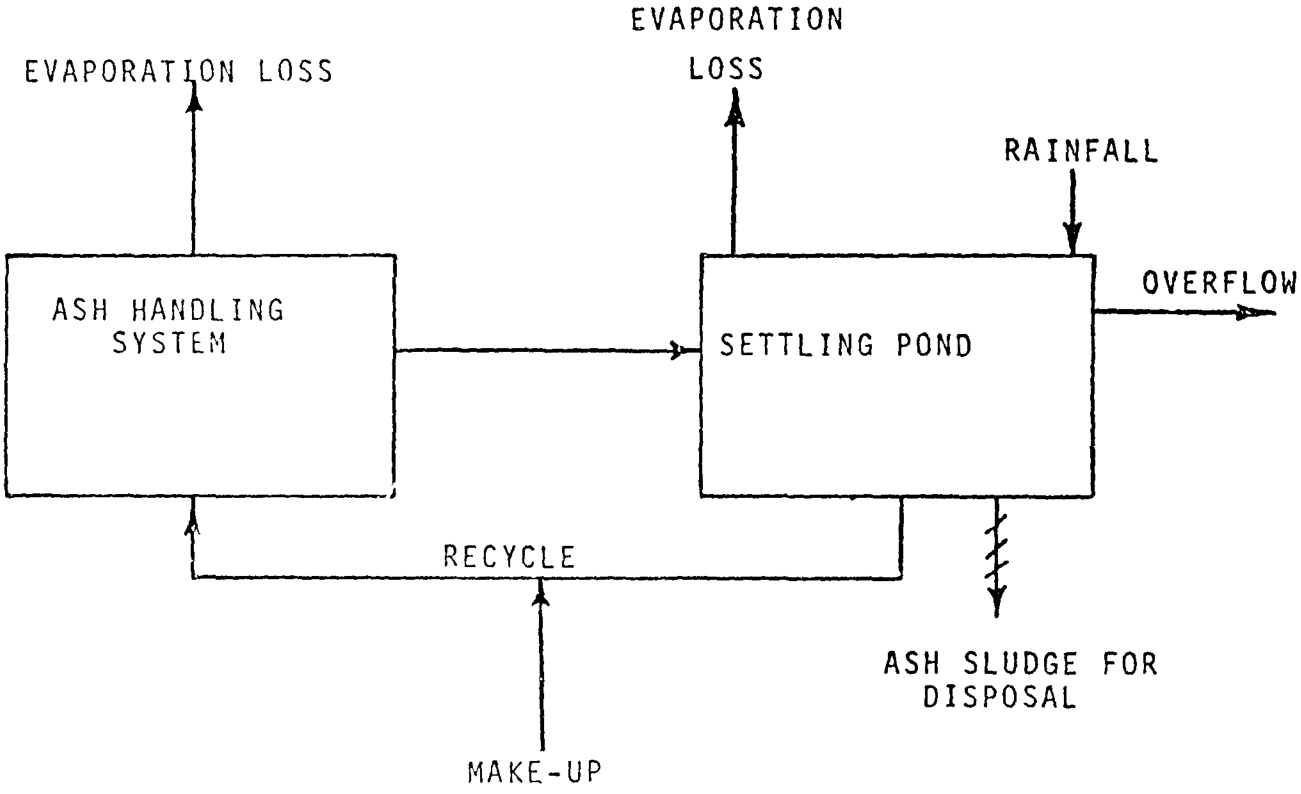


FIGURE V-8. Flow Diagram for Recirculating Bottom Ash System

Table V-6. ASH DISPOSAL METHODS

PLANT NO.	TYPE OF PLANT	ASH DISPOSAL SYSTEM FLY ASH	 BOTTOM ASH
9600	Oil and Gas	None Required	
9650	Oil and Gas	1	2
9369	Oil and Gas	3	4
9371	Oil and Gas	3	2
7485	Coal, Oil, and Gas	3	4
8816	Oil and Gas	1	2
9585	Gas	None Required	
7116	Oil and Gas	3	4
8696	Oil and Gas	9	2
8135	Oil and Gas	None Required	
9163	Coal	3,5	4
6387	Coal	3	6
8392	Gas	None Required	
6293	Coal	3	7
7308	Oil	None Required	
8875	Oil and Gas	1	2
7968	Coal and Gas	3	7
6421	Oil and Gas	None Required	
6214	Coal	4	4
6294	Coal and Gas	3	8

Key:
(1) Soot blowing steam
(2) Fireside washing
(3) Dry collection system from electrostatic and/or mechanical precipitators, ash then hauled to landfill.
(4) Dry collection system-ash landfilled.
(5) Air wash in stack to control fly ash-discharges to POTW
(6) Wet collection system with settling sump-(overflow from sump goes to POTW)
(7) Vacuum system using steam, ash landfilled, condensate from steam goes to POTW.
(8) Wet system discharging to surface water.
(9) Wet system, does not discharge to POTW

pressure steam (soot blowing steam), and passes through the stack to the atmosphere.

Bottom Ash. Some of the oil-fired plants visited needed fireside washing to remove bottom ash, other plants had dry collection systems that removed ash for land disposal.

Coal-Fired Plants. The amount of ash produced by coal-fired plants is much greater than that produced by oil-fired plants, requiring the use of more complex ash-handling systems.

Fly Ash. Electrostatic precipitators or mechanical cyclones are used in most of the coal-fired plants to collect fly ash. The collection systems from these units are usually dry, and the final ash disposal is on land. One plant, No. 9163, used an additional system for fly ash control, consisting of a wash in the stack that discharged excess fly ash to a POTW.

Bottom Ash. Methods for disposing of bottom ash varied widely among the coal-fired plants that were visited. Plants 7485 and 9163 used dry collection systems for the land disposal of bottom ash. Plant 6387 was the only plant visited that used a wet transport system in combination with a settling sump. Two plants No. 6293 and 7628 used a vacuum collection system with steam. One plant, No. 6294, has an ash settling basin which overflows to surface water. Plant No. 6214 has a totally dry ash system.

Table V-7 shows raw waste loading for two plants, 6293 and 6387.

Wastewater Treatment

Oil-Fired Plants. Because of the small quantities of ash produced by oil-fired plants, none of the visited plants had ash treatment systems.

Coal-Fired Plants. Only one plant, No. 6387, used a settling basin in conjunction with a wet ash transport system. Most of the other coal-fired plants had no need for an ash treatment system, since these plants used dry collection systems, followed by land disposal.

Effluent Waste Loads

Oil-Fired Plants. Effluents from ash cleaning of oilfired plants are present for those plants which used fireside cleaning for ash removal.

Coal-Fired Plants. Plant No. 6387 is the only visited plant that discharged a significant amount of waste from an ash handling system to a POTW. The discharge consists of the overflow from the ash settling sump. Treated effluent is shown in Table V-8.

DRAINAGE

Floor and Yard Drains. Floor and yard drains collect wastes from leakage and numerous cleaning operations, and may discharge to a POTW. The waste will contain dust, fly ash, coal dust from coal-fired plants, oils, and detergents.

Coal Pile. The storage of large quantities of coal is necessary for coal-fired plants to insure continuous operation and to simplify delivery by the supplier. A 90-day supply is normally maintained. Coal storage piles are of two types: active and storage. Active piles are used continuously and are subject to infiltration by rainwater. Storage piles are used for the long-term storage of coal, and are usually protected from rainfall with some sort of seal, which can be either a layer of asphalt or a layer of fine coal dust covered with lump coal.

Waste discharges from coal storage piles are the product of drainage from rainfall. This drainage can be either acidic or alkaline. Acid drainage is the result of the reaction of pyrite (FeS_2) with water and oxygen, which produces iron sulfate and sulfuric acid. This type of drainage is highly acidic, has a low pH, and contains a large amount of ferrous iron and some aluminum. Alkaline drainage occurs when acid drainage is neutralized by alkaline material present in the coal, or when the coal has a low pyrite content. Alkaline drainage is characterized by a pH of 6.5 to 7.5 or greater, little acidity, and significant concentrations of ferrous iron. If the ferrous iron concentration is high enough, the iron may precipitate upon oxidation and hydrolysis.

Drainage from coal piles may contain in addition to the aforementioned constituents, high concentrations of dissolved solids and significant amounts of copper, zinc, and manganese. Other materials may also be present that are the result of the reaction of sulfuric acid with minerals and organic compounds present in the coal.

Raw Waste Load

Coal Pile. Almost all of the plants that were visited allowed coal pile drainage to drain to either the surface water, storm sewers, or nearby land. An exception was plant No. 9163, which stored all of its coal under roof, thus eliminating any drainage problems.

Table V-7. RAW WASTE FLOWS AND LOADINGS - ASH HANDLING

PLANT NO.	6293		6387	
WASTEWATER SOURCE	Ash Transport Blowdown		Ash Transport Blowdown	
FLOW	L/Day 27252	L/MWH 113.55	L/Day 45420.0	L/MWH 126.16
PARAMETER	mg/l	g/MWH	mg/l	g/MWH
BOD_5	3.0	0.34	1.2	0.15
Bromide (Bromate)	---	----	---	-----
COD	1235.0	140.23	290.0	36.58
Chromium	0.37	0.04	0.12	0.015
$Chromium^{+6}$	0.030	0.003	0.009	0.001
Copper	0.16	0.018	0.20	0.025
Cyanide (Total)	0.005	0.0005	0.112	0.014
Iron	76.0	8.62	6.2	0.78
Nickel	0.24	0.03	0.03	0.003
Oil and Grease	1.0	----	1.0	-----
Phosphate (Total)	3.4	0.38	0.02	------
Total Dissolved Solids	388.0	44.05	1894.0	238.95
Total Suspended Solids	1144.0	129.90	1651.0	208.30
Total Solids	1532.0	173.95	3545.0	447.26
Surfactants	------	------	------	-------
Zinc	0.55	0.06	0.08	0.01

Table V-8. EFFLUENT FLOWS AND LOADINGS - ASH HANDLING

PLANT NO.	6387	
WASTEWATER SOURCE	Settled ash transport effluent	
FLOW	L/Day 45420.0	L/MWH 126.16
PARAMETER	mg/l	g/MWH
BOD$_5$	1.0	------
Bromide (Bromate)	-----	------
COD	43.1	5.43
Chromium	0.02	------
Chromium^{+6}	0.011	0.001
Copper	0.2	0.002
Cyanide (Total)	0.012	0.001
Iron	0.33	0.04
Nickel	0.03	------
Oil and Grease	1.0	------
Phosphate (Total)	0.02	------
Total Dissolved Solids	2980.0	375.97
Total Suspended Solids	70.0	8.83
Total Solids	3050.0	384.80
Surfactants	-------	--------
Zinc	0.02	0.002

General chemical characteristics of coal pile drainage were discussed under the previous heading. Reference 16 lists ranges for some of the elements present in coal pile drainage, which are shown below:

Element	Concentration Range, mg/l
Copper	1-4
Iron	0.1-5
Zinc	1-15

Floor and Yard Drains. Drainage from floor and yard drains in most cases can be assumed to be a negligible waste source. Many plants exercise meticulous care to prevent oil leaks and spills from reaching floor drains by using drip pans and oil absorbing materials. Some plants particularly those in open areas or in dry regions, have no need for yard drains and have no drains installed.

Reference 16 list characteristics of wastes from yard and floor drains, which are summarized below:

Parameter	Concentration Range (mg/l)
BOD	2-4
TSS	0-5
pH	Low-Neutral
Surfactants	Present
Chromium	0-20
Lead	Present
Phosphorous	0-10
Oil and Grease	Present

Wastewater Treatment

None of the plants that were visited used any type of coal pile drainage treatment system.

One plant No. 7116 discharged floor drainage (along with other wastes) to a settling tank before discharge to a POTW. Other plants discharged floor and yard drainage without treatment either directly to surface water or to a POTW.

Effluent Waste Loads

Information was not available on treated wastewater before discharge to the POTW.

AIR POLLUTION CONTROL EQUIPMENT

Liquid waste disposal problems associated with air pollution control equipment are mainly limited to systems for the control of SO_2. Control systems for SO_2 can be further divided into "throwaway" and "recovery" processes. Throwaway processes produce a sludge or cake that must be disposed of. Recovery processes produce either elemental sulfur, sulfuric acid, or gypsum, which are marketable to some degree and have limited disposal problems. The following discussion will be limited to a throwaway process.

The greatest number of existing flue gas desulfurization systems (including recovery and throwaway) use tail-end scrubbing with lime and/or limestone. Those scrubbing systems, installed after the boiler, remove particulates as well as sulfur dioxide by reacting the flue gas with slurries of lime or limestone forming calcium sulfates and sulfites. The calcium sulfate/sulfite sludge is usually piped to large settling ponds.

A small number of existing throwaway systems are of the double-alkali type. In these systems, sodium or ammonium salts are used as a scrubbing solution. After contacting the flue gas, the scrubbing solution is reacted with limestone or lime to precipitate calcium sulfite and sulfate and regenerate the solution for recirculation to the scrubber. Scrubber wastes consist of a dry filter cake.

Figure V-9 shows a flow diagram for an air pollution control scrubbing system.

Water Use

None of the twenty-three plants visited in the study used water to control SO_x emissions. This can be accounted for by the fact that the majority of the plants burned low sulfur (1 percent) coal or oil thereby eliminating the need for air pollution control devices.

Raw Waste Load

None of the utilities visited had flue gas desulfurization equipment. Wastes from these systems are mostly in the form of sludges, which are disposed of on land.

Wastewater Treatment

None of the plants discharged SO_x removal wastewaters to the POTW.

Effluent Waste Load

Information was not available on treated wastewater.

MISCELLANEOUS WASTE STREAMS

Sanitary Wastes. Sanitary wastes from steam-electric plants are similar to municipal domestic wastes with the absence of laundry or kitchen wastes. The volume of waste flow is dependent upon the number of employees.

Plant Laboratory Wastes. Many steam-electric plants have laboratories for the chemical analysis of various process streams within the plant. Depending on the analyses performed, the waste from this source will contain a large variety of chemicals, albeit in small amounts.

Intake Screen Backwash. Power plants that withdraw cooling water from a natural body, such as a lake or river, use traveling screens to prevent debris from entering the intake system. The debris from these screens are usually collected.

Supplementing Cooling Water Systems. These cooling systems are generally maintained for such uses as bearing and gland cooling for pumps and fans. The systems may be oncethrough or recirculating. Chemicals are not used in oncethrough systems, except for occasional shock chlorination. Recirculating systems use water of high purity, supplemented by pretreated makeup water. Chromates, borates, and nitrates are used in recirculating systems to prevent corrosion.

Construction Activity. The construction of buildings and equipment adjacent to power plants can cause the presence of additional amounts of suspended solids and turbidity in the storm-water runoff due to the erosion of soil disturbed by the construction activity.

Water Use

Housekeeping. Housekeeping water usage, which includes floor washing and sanitary water (bathrooms, sinks, etc.), amounts to less than one percent of the total. Only one plants of the twenty-three in the study had any substantial floor wash water usage these being plant No. 6294 with 0.29 liters per MWH. The following table lists the water for sanitary purposes.

Plant No.	Water Usage, Liters/MWH
9600	1.05
9369	7.96
8816	2.74
9585	6.23
9163	4.29
6387	6.73
8356	26.12

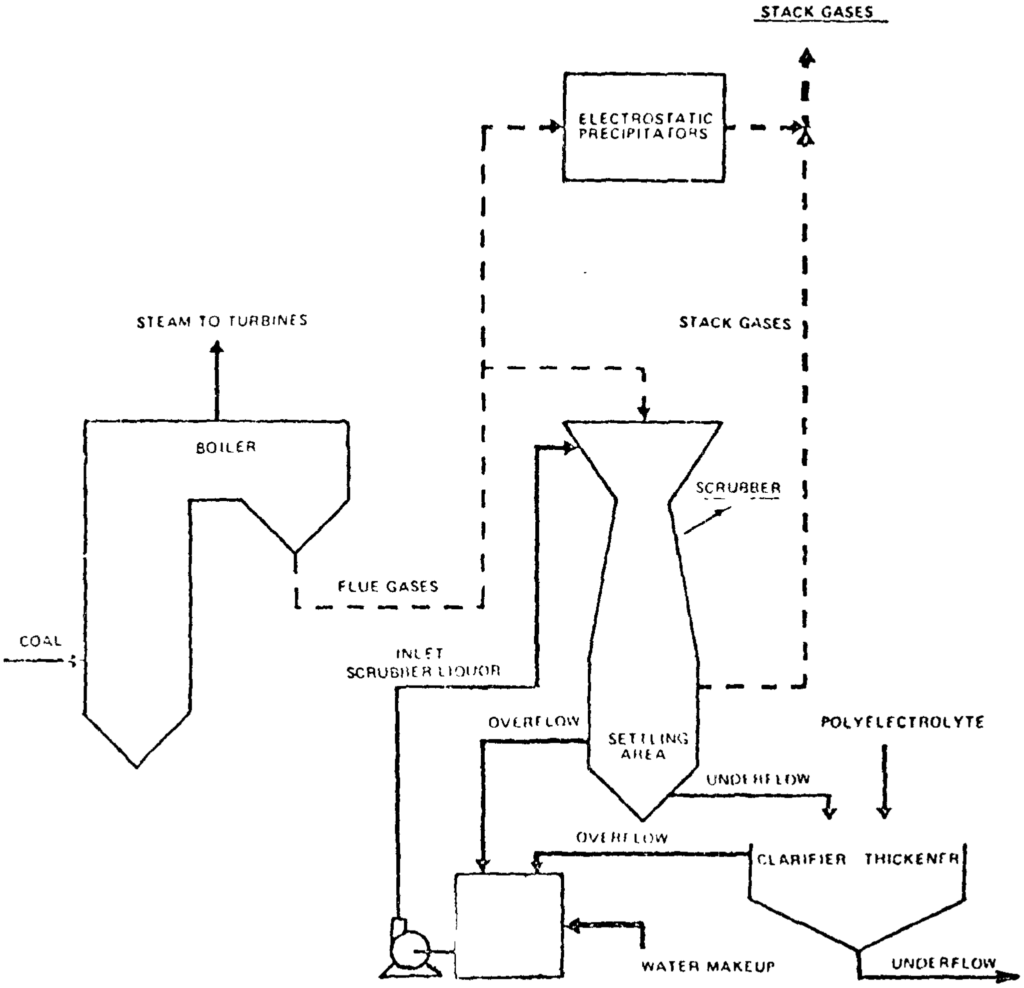


FIGURE V-9. Flow Diagram For Air Pollution Control Scrubbing System (Ref. 14)

6293	4.73
8392	5.03
8875	0.4
7968	11.55
6421	6.00
6294	1.74

Miscellaneous Cooling. Miscellaneous cooling needs include bearing cooling water, cooling of compressors, and other extraneous equipment cooling needs. Water usage varied for six plants from a low of 1.59 liters per MWH for plant No. 9396 to a high of $1.45x10^{4}$ for plant No. 8356. Using the least squares analysis method for the normalized data, a coefficient of determination of 0.945 was calculated indicating that approximately 94 percent of the data variance could be accounted for by the least squares straight line.

Raw Waste Load

Sanitary Wastes. Reference 14 states that the per capita sanitary waste load is generally 25-35 gal/day (94.5-132 liters/day) from steam-electric power plant. The reference also lists the number of employees per MW that may be expected to be found at typical power plants:

operational personnel: 1 per 20-40 MW
maintenance personnel: 1 per 10-15 MW
administrative personnel: 1 per 15-25 MW

The flow, BOD$_5$, and suspended solids per capita load can be estimated by the following (14):

	Flow	BOD5	TSS
Office-Administrative (per capita)	0.95 cu m/day (25 gpd)	30g (0.07lb)	70g (0.15 lb)
Plant (per capital)	0.133 cu m/day (35 gpd)	40g (0.09 lb)	85g (0.19 lb)

Plant Laboratory Wastes. The volume of wastes from in-plant laboratory can be assumed to be negligible. Reference 14 suggests that if a toxic materials problem is found to originate from a laboratory drain, it may be appropriate to either: (1) change the test procedure, (2) contain the waste for seperate treatment, or (3) remove the waste from the site.

Supplementary Cooling Water Systems. Wastes are discharged from recirculating cooling systems during blowdown, which may typically be twenty liters per day with a settleable solids content of 1-2 ppm (14). Additional wastes are discharged during drainage and cleaning operations, which are infrequent.

Plants which use once-through systems may discharge the effluent from the entire system to a POTW. This waste stream will probably contain chlorine, and the stream is usually of significant volume.

Construction Activity and Intake Screen Backwash. The nature and duration of these wastes do not contribute significantly to the total waste load.

Wastewater Treatment

Sanitary Wastes. Sanitary wastes are generally discharged directly to POTW or septic tanks without treatment. An exception is plant 7116, which pretreats sanitary wastes (along with other wastes) in a settling tank before discharge to a POTW.

Plant Laboratory Wastes. Most plants combine laboratory drains with other sanitary plant plumbing, and discharge the waste without pretreatment.

Supplementary Cooling Water Systems. Supplementary cooling system wastes are usually discharged directly, although one plant 7116, discharged the waste to a settling tank before discharge to a POTW.

Construction Activity and Intake Screen Backwash. Most plants do not treat these wastewaters. Intake screens are generally backwashed into the water source.

Effluent Waste Loads.

Information is not available on treated effluent from miscellaneous waste streams.

THE POTW PROCESS

Preliminary Physical Treatment

Most POTW employ initial physical treatment of wastewater for the removal of course materials, settleable solids, grease, and floating material.

Bar Racks and Comminutors. These devices are used as the first step in wastewater treatment to remove large solid materials. Bar racks consist of large, parallel steel bars placed perpendicular to the flow of wastewater. The bars trap and retain large solids, which are removed mechanically by a series of vertically-moving rakes connected to a motor-driven, endless chain belt. The solids are scraped off the racks with large mechanical arms, and may then either be collected for land disposal or ground in disintegrators and returned to the flow. Smaller POTW may use comminutors, which are motor-driven cutting devices partially submerged in a narrow channel, to grind up large materials as they pass through.

Grit Chambers. Grit chambers are usually found in larger POTW. They are generally located after bar racks, and are designed to remove sand, cinders, or other heavy particles that have high settling velocities. Grit chambers may be of two types: horizontal-flow, and aerated. Horizontal-flow grit chambers consist simply of a channel designed to maintain a constant flow velocity regardless of the volume of water passing through the channel. The flow velocity is lowered sufficiently over that of the influent wastewater to allow grit to settle to the bottom. Removal of the grit may be done either mechanically or by hand.

Aerated grit chambers consist of a spiral-flow aeration tank. The velocity of flow in aerated chambers is determined by the volume of the tank and the quantity of air that is supplied. Aerated grit chambers are always cleaned mechanically.

Primary Sedimentation. Primary sedimentation is used after preliminary removal of solids in racks and grit chambers and prior to biological treatment. The purpose of primary sedimentation, when used prior to biological treatment, is to reduce the suspended solids and BOD load on the biological treatment units. This is accomplished in large, rectangular (or circular) sedimentation tanks that provide a sufficient detention time for the removal of settleable solids and floating material. Grease and other floating materials are skimmed off from the surface with skimmers. Solids that settle to the bottom of the tank (known as primary sludge) are mechanically pushed into a hopper, where they are collected for further treatment. Primary sedimentation tanks, if designed properly and operated correctly, will remove 50 to 65 percent of the suspended solids in the influent wastewater and from 25 to 40 percent of the BOD. If primary sedimentation is used as the only means of treatment, the effluent is usually chlorinated to remove pathogens.

Secondary Biological Treatment

Secondary biological treatment is used to convert soluble and colloidal organic material into settleable flocculant material that can be removed in sedimentation tanks. Two types of biological treatment processes are most often employed: (1) the activated-sludge process, and (2) trickling filters.

Activated-Sludge Process. The activated-sludge process consists of an aerated basin containing a large mass of microorganisms and flocculated solids, known as the mixed liquor, followed by a sedimentation tank in which the solids are removed. The sedimentation tank may either be part of the same structure as the aeration basin, or it may be completely separate. Part of the solids that settle in the sedimentation tank (the secondary sludge) is removed for further treatment, and part is recycled to the aeration basin. The effluent from the sedimentation tanks is usually chlorinated.

Bacteria make up the largest portion of the microorganisms present in the activated sludge, and are responsible for the majority of the waste stabilization that occurs. The mechanisms by which bacteria stabilize a waste is twofold, consisting of: (1) consumption of organic matter, which is partially oxidized to lower energy compounds and partially converted to new cellular material, and (2) the production of polymers and slime that bind bacterial cells and other suspended material into flocculant particles that can be removed by sedimentation. Other microorganisms may also be present, such as protoza, which consume bacteria that have not flocculated, and rotifers, which consume small floc particles that have not settled. Activated sludge systems are usually from 55-95 percent efficient in removing BOD, and from 55-95 percent efficient in removing suspended solids (Figure V-10).

Trickling Filters. Trickling filters consist of a bed of rocks or plastic material that support a growth of microbial material (slime layer). Wastewater is sprayed over the top of the bed, which is circular, with a rotating distributor. As the waste percolates through the bed, organic material is adsorbed onto the slime layer. At periodic intervals, partly because of the increase in thickness of the slime layer, the microorganisms in the layer lose their ability to cling to the surface of the filter media and the slime layer is washed off by the wastewater (a process called "sloughing"). (Figure V-10).

Trickling filters are divided into two categories: low-rate and high-rate, based on organic loading rates. Both types of filters achieve equivalent BOD removal efficiencies, but high-rate filters are advantageous since they have a higher rate of BOD removal (and thus can accept higher influent flow rates) than low-rate filters. This is achieved by recycling a portion of the influent to return viable organisms back to the filters. Low-rate filters have no recycle. Both types of filters are followed by a settling tank (clarifier) to remove suspended solids produced during sloughing. The effluent from the settling tank is generally chlorinated. Trickling filters are from 50-95 percent efficient in the removal of BOD, and 30-92 percent efficient in the removal of suspended solids.

Figure V-11 shows a wastewater treatment process diagram utilizing activated sludge or trickling filters.

Treatment and Disposal of Sludge.

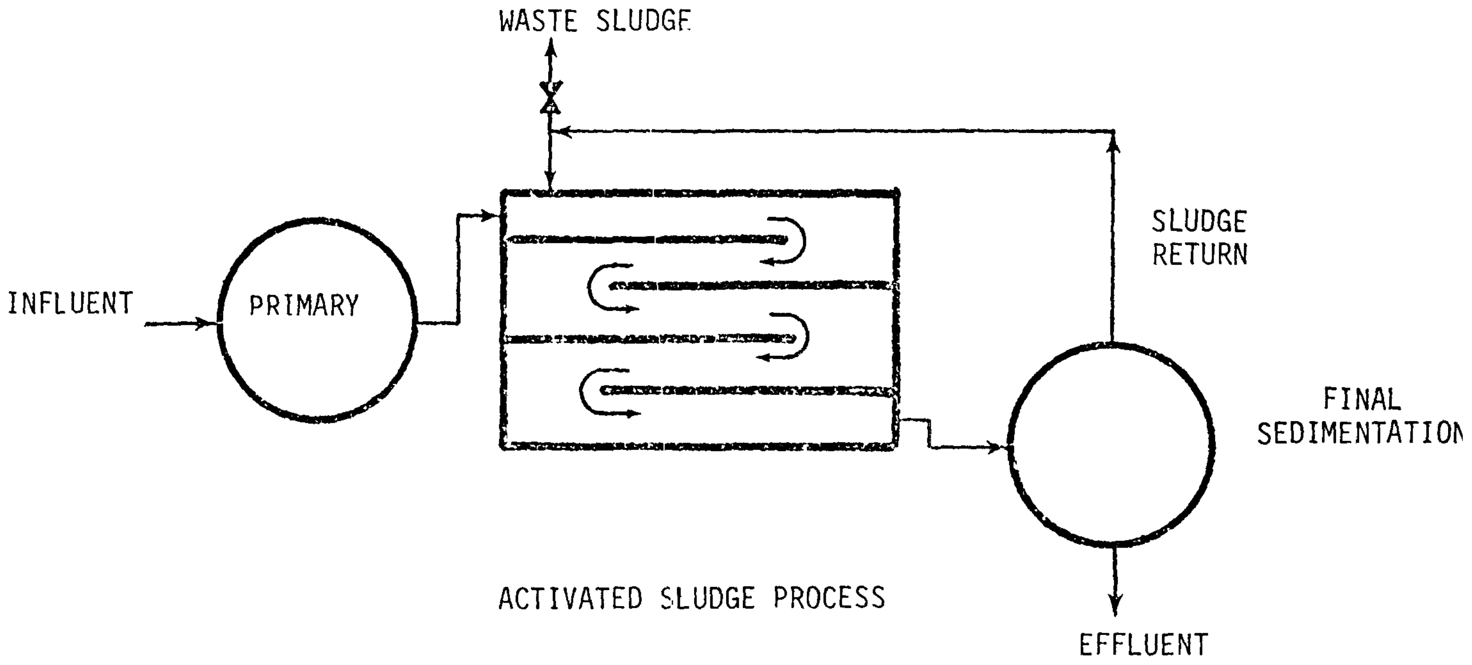
The problem of disposing of sludges produced during primary and secondary treatment is one of the most complex tasks faced by the engineer. Techniques for dealing with sludges are varied, but most involve: (1) digestion, followed by (2) conditioning, and (3) dewatering and drying (Figure V-11).

Digestion is a biological process for reducing the volume of sludge. Two types of digesters are in use: anaerobic, and aerobic. Anaerobic digesters are closed, heated tanks in which various microorganisms decompose organic and/or inorganic matter without the presence of oxygen, forming methane, carbon dioxide, and sludge solids. The methane that is involved during the process can be used as a fuel, and its rate of production is one of the best measures of the satisfactory operation of the digester. Chemical conditioning, followed by centrifugation or vacuum filtration, is usually used to treat sludge solids during anaerobic digestion. Chemical conditioning involves the use of ferric chloride, lime, alum, or organic polymers to coagulate the solids and release absorbed water. Centrifugation and vacuum filtration are physical operations that are used to remove water from the sludge solids prior to final disposal.

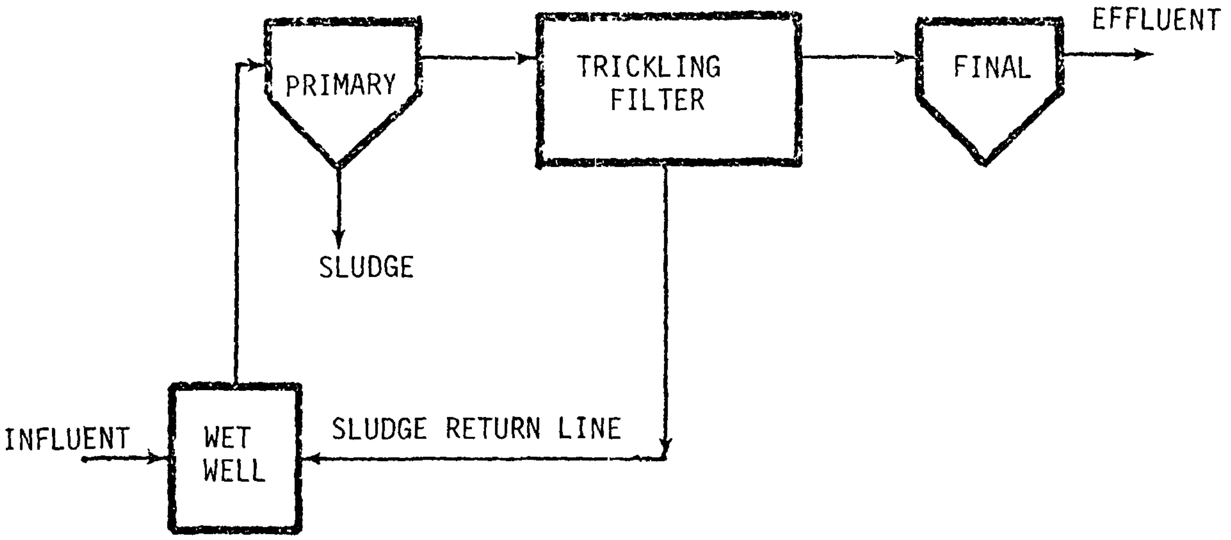
Aerobic digestion is much like the activated sludge process, involving consumption of organic compounds in sewage by an aerated mass of microorganisms. As the supply of organic material run out, the microorganisms begin to consume their own protoplasm. Sludge solids from aerobic digesters are stable and are more easily dewatered by vacuum filtration or drying on sand beds.

Advanced Waste Treatment

Many chemical constituents present in wastewater, especially nitrogen and phosphorus, are slightly affected by

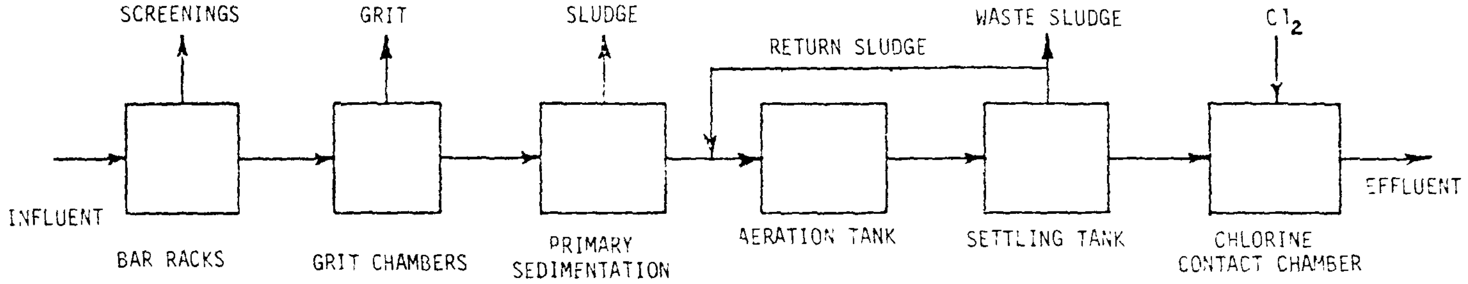


ACTIVATED SLUDGE PROCESS

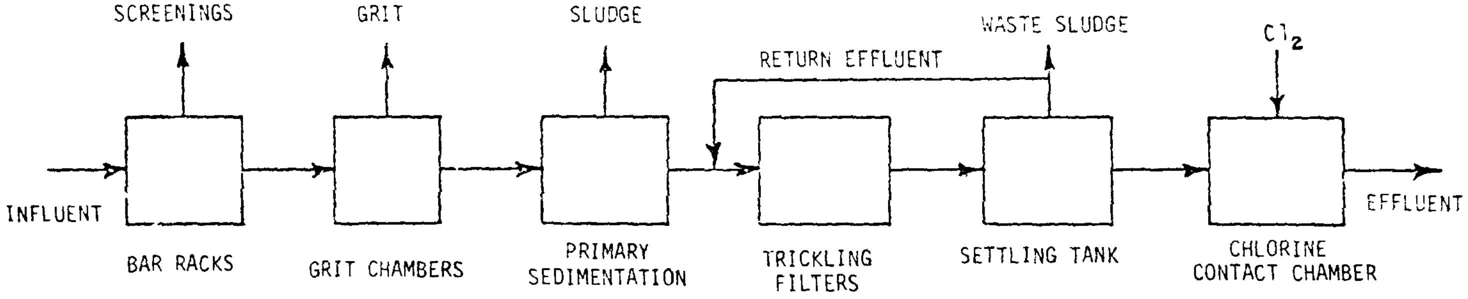


TRICKLING FILTER PROCESS

FIGURE V-10. Flow Diagram of Secondary Treatment Methods



ACTIVATED SLUDGE
TREATMENT SCHEME



TRICKLING FILTER
TREATMENT SCHEME

FIGURE V-11. Wastewater Treatment Flow Diagram

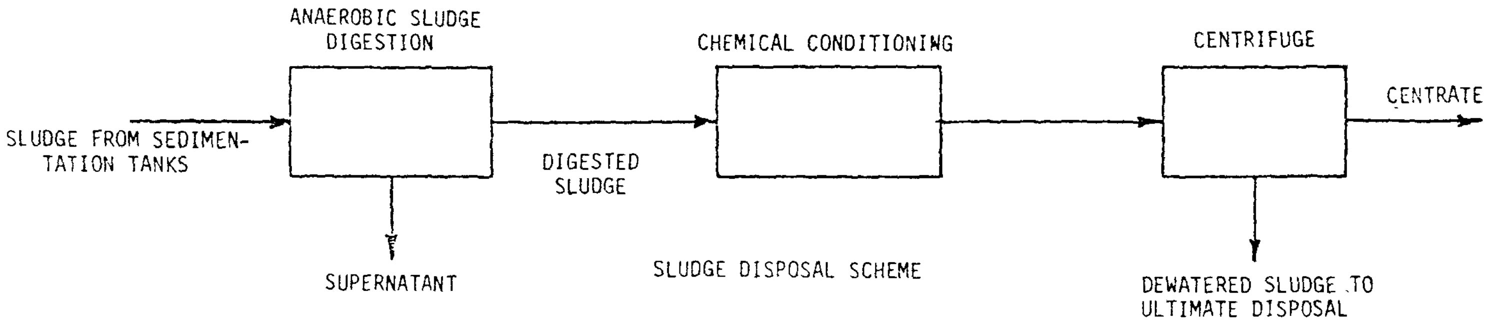


FIGURE V-12. Flow Diagram for Sludge Treatment conventional primary and secondary treatment. Since these chemicals can have adverse effects on the receiving water by promoting the growth of algae and other unwanted aquatic vegetation, their removal is desirable in some cases. Although tertiary treatment processes are still uncommon, their use is receiving considerable attention. Two processes, nitrification for the removal of nitrogen, and precipitation for the removal of phosphorus, will be discussed.

Nitrification-Denitrification. This process appears to be the most promising for the removal of nitrogen. The technique involves aerobic conversion of ammonia to the nitrate form (nitrification), followed by anaerobic conversion of the nitrates to nitrogen gas (denitrification). Both steps involve the production of specialized groups of bacteria, and require detailed attention to operating and environmental conditions. Denitrification requires the addition of a supplemental carbon source for successful operation; methanol is usually used. Nitrification-denitrification is from 60-65 percent efficient in removing nitrates. Figure V-13 shows a flow diagram of the nitrification-denitrification process.

Chemical Precipitation. Precipitation of phosphorus can be achieved by the addition of chemicals such as lime, alum, and ferric chloride, or sulfate. These chemicals are usually added to the raw wastewater and the phosphorus is precipitated during primary sedimentation, however, these chemicals can also be added in the activated-sludge aeration tank or to the secondary clarifier. Removal of phosphates by precipitation in primary sedimentation tanks is from 90--95 percent efficient.

Flows of POTW Receiving Steam-Electric Wastewaters

The wastewaters discharged by steam-electric plants vary greatly in flow and waste loadings. For the twenty-three plants visited during this study, the steam-electric wastewaters represented less than five percent of the total POTW influent. Table V-9 lists the combined discharge rate for each steam-electric plant along with the associated POTW influent flow and treatment scheme.

Raw Waste Load

Waste loads in the total combined waste streams discharge from power plants are affected by any occurrence in the steam-electric which use and discharge water. The waterborne waste loads in the combined discharge for six (6) plants are shown in Table V-10. The major pollutants are chemical oxygen demand and dissolved and total solids, with lesser values of iron, nickel, phosphates and total and hexavalent chromium.

WASTE COMPARISON

Effluent data gathered from the eight (8) plants sampled during this study were compared with similar data gathered in support of the "Development Document for Effluent Limitations Guidelines and Standards of Performance for the Steam Electric Power Generating Point Source Category" (14). Comparison was made to identify similarities and differences in the quality and quantity of aqueous plant effluents. Waste streams for which data was available for comparison include:

- Recirculating Condenser Cooling Water
- Water Treatment Wastes
- Boiler Blowdown
- Ash Handling Wastes

These data may be found in Table V-11.

Recirculating Condenser Cooling Water

Flow data in this study tended to coincide with lower flows reported in the development document (14) and were similar. Concentrations of BOD, phosphate, dissolved solids, suspended solids, total solids, and zinc observed in this study were within the range of those reported in the Development Document. Concentrations of chromium, copper, iron and nickel observed in this study tended to be lower than those reported in the development document. This difference is probably due to a number of factors, including lower influent loadings of these heavy metal components, and less corrosive nature of the intake waters.

Water Treatment Wastes

Flows and parameter concentrations of wastes observed in this study were within the range of those reported in the development document (14). Pollutants observed were identical to those reported in Reference 14.

Boiler Blowdown

Flow data for boiler blowdown observed in this study was within the range of those reported in the development document. Pollutants observed were identical to those of Reference 14. Concentrations of all parameters observed in

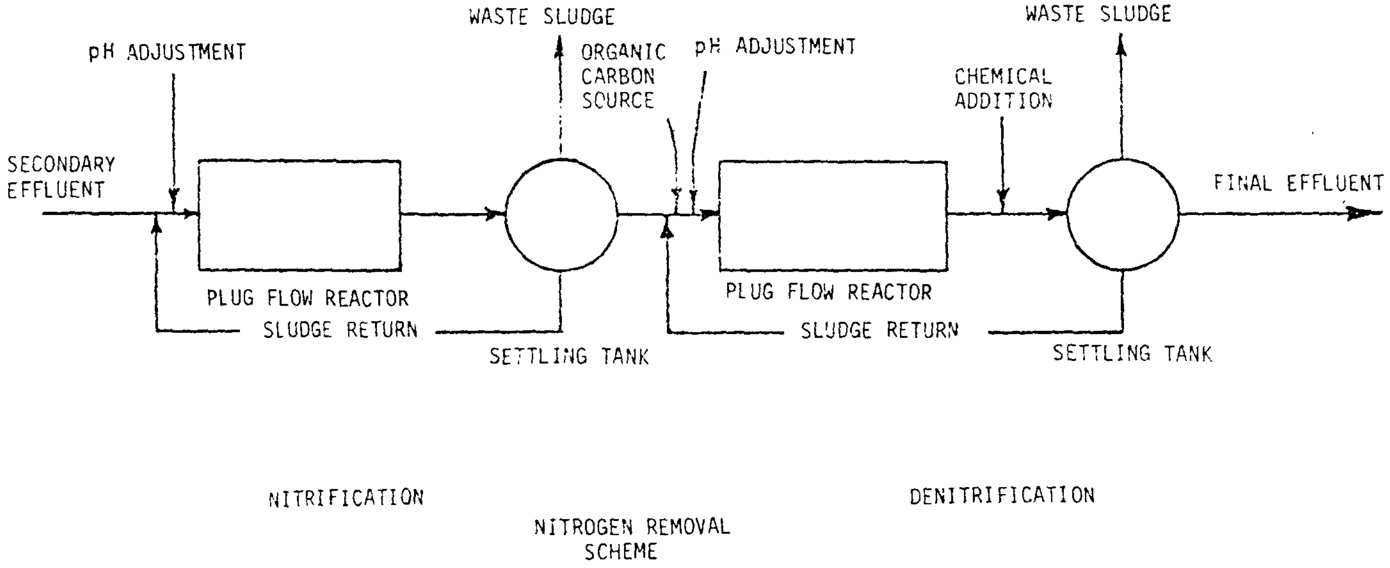


FIGURE V-13. Flow Diagram of Nitrification-Dentrification Process

Table V-9. POWER PLANT AND POTW FLOWS

Plant No	Combined Flow to POTW, gpd (l/d)	POTW Average Flow, gpd (l/d)	% of POTW Flow	POTW Treatment Scheme
9600	No data (plant has been using POTW for only one year)			
9650	100,00 (378,000)	97.5 x 10^6 (369 x 10^6)	0.10	Activated sludge, anaerobic digestion
9369	2,350 (8,880)	2.4 x 10^6 (9.1 x 10^6)	0.098	Rotating biological surfaces; anaerobic digestion
9371	15,000 (56,700)	10.0 x 10^6 (22.7 x 10^6)	0.15	Activated sludge, aerobic digestion
7485	1,580 (5,970)	300,000 (1.1 x 10^6)	0.50	Activated sludge, aerobic digestion
8816	2,000 (7,560)	350 x 10^6 (1,320 x 10^6)	0.01	Activated sludge, anaerobic digestion
9585	600 (2,270)	4.5 x 10^6 (17.0 x 10^6)	0.01	Oxidation pond
7116	Data incomplete	3.5 x 10^6 (13.2 x 10^6)	---	Activated sludge
8696	72,000 (272,293)	350 x 10^6 (1,320 x 10^6)	0.02	Activated sludge, anaerobic digestion
8135	150,400	No POTW at present - to be hooked up to West Palm Beach POTW in 1978 - Sewers presently run to ocean		
9163	46,900 (177,000)	10 x 10^6 (38 x 10^6)	0.47	Trickling filters; anaerobic digestion
6387	9,500 (35,900)	220,000 (832,000)	4.3	Trickling filters; no digestion
8392	126,000 (476,000)	1.5 x 10^6 (5.7 x 10^6)	8.4	Activated sludge, aerobic digestion
6293	9,100 (34,400)	2 x 10^6 (7.6 x 10^6)	0.46	Activated sludge trickling filters anaerobic digesters
7308	902,000 (3.41 x 10^6)	315 x 10^6 (1,190 x 10^6)	0.29	Primary treatment only secondary treatment facilities being built
8875	423,000 (1.60 x 10^6)	31.1 x 10^6 (120 x 10^6)	1.4	Activated sludge, trickling filters, anaerobic digestion
7968	Data incomplete	---	---	---
6421	24,650 (93,308)	1.4 x 10^6 (5.3 x 10^6)	1.76	Activated sludge
6214	No data - operates only 50 hours/yr	1.4 x 10^6 (5.3 x 10^6)	---	Activated sludge
6294	4,250 (16,088)	1.4 x 10^6 (5.3 x 10^6)	0.30	Activated sludge

Table V-10. RAW WASTE FLOWS AND LOADINGS - COMBINED DISCHARGE TO POTW

PLANT NO	6387		8392		7308		8696*		6293*		8135*	
WASTEWATER SOURCE	Combined Discharge		Combined Discharge		Combined Discharge		Combined Discharge		Combined Discharge		Combined Discharge	
FLOW	L/Day 518,000	L/MWH 1870	L/Day 233,000	L/MWH 755	L/Day 2,950,000	L/MWH 223	L/Day 272,000	L/MWH 39.9	L/Day 35,600	L/MWH 150	L/Day 254,000	L/MWH 593
PARAMETER	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH	mg/l	g/MWH
BOD_5	8.4	16	20	15	6.0	1.4	24.4	0.974	11.4	1.71	13	7.7
Bromide (Bromate)	---	----	----	-----	----	-----	------	-----	-----	-----	18.1	10.7
COD	49.0	91.6	11.8	8.91	50	11	3.64	1.45	123	18.4	136	80.6
Chromium	<0.02	Uncertain	8.1	6.1	1.76	0.403	<0.02	<0.02	0.033	0.005	9.7	5.7
$Chromium^{+6}$	0.006	0.01	8.0	6.0	0.66	0.15	0.01	0.0004	0.020	0.003	7.19	4.26
Copper	0.02	0.04	0.04	0.03	0.45	0.10	0.46	0.018	0.5	0.008	0.03	0.02
Cyanide (Total)	0.006	0.01	<0.005	<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	0.12	0.71
Iron	0.64	1.2	0.71	0.54	14.7	3.37	0.88	0.035	5.79	0.868	0.12	0.71
Nickel	<0.03	Uncertain	<0.03	<0.03	12	2.7	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Oil and Grease	<1.0	Uncertain	1.2	0.91	5.8	1.3	2.3	0.092	<1.0	<1.0	<1.0	<1.0
Phosphate (Total)	-----	-----	----	-----	-----	------	0.05	0.002	4.4	0.66	5.8	6.4
Total Dissolved Solids	1454	2719	16	12	2080	476	2479	98.9	580	87	1298	763
Total Suspended Solids	241	451	<1.0	<1.0	226	51.7	70.2	2.8	189	28.3	5.6	3.3
Total Solids	1695	3170	16	12	2306	528	2549	102	770	115	1304	773
Surfactants	0.024	0.04	-----	------	-----	-----	-----	------	<0.011	<0.011	0.059	0.035
Zinc	0.07	0.1	2.6	2.0	1.47	0.337	0.11	0.0044	0.045	0.0068	0.56	0.33

* Quantities of parameters in combined discharge calculated by fractional addition of parameters in seperate contributing streams

this study were similar to those reported in the development document with the exception of BOD, and zinc. BOD values observed in this study tended to be higher than those reported in the development document. Observed zinc values tended to be lower. Zinc concentrations are understandably lower for all discharges observed in this study due to use of municipal water as influent water.

Ash Handling Wastes

Wastewater flows of ash handling wastes observed in this study were within the range of those reported in the development document (14). Pollutants observed were identical to those reporte in Reference 14. Concentrations of parameters observed in this study were within the range of those reported in the development document, with the exception of phosphate. Phosphate concentrations observed in this study were higher than those reported in the development document. Higher maximum phosphate concentrations are probably due to the variable nature of coal impurities.

Summary

Overall, values, of effluent flows and parameter concentrations observed in this study were similar to those reported in data referenced in the development document (14). Pollutants observed were identical to those reported in Reference 14. The few parameters in this study that lay outside the range of development document data tended to be lower, reflecting the higher quality of the municipal water used as influent water for the stations contacted in this study. Therefore, it may be concluded that the stations reported in by the results of this study discharge pollutants similar to those (direct dischargers) affected by the development document (14).

Table V-11.

COMPARISON OF PARAMETER VALUES

PLANT RAW WASTES

PARAMETER \ WASTE STREAM		RECIRCULATING CONDENSER COOLING WATER		WATER TREATMENT WASTES		BOILER BLOWDOWN		ASH HANDLING WASTES	
		THIS STUDY	REF.14	THIS STUDY	REF.14	THIS STUDY	REF.14	THIS STUDY	REF.14
FLOW (L/DAY)	LO	53,600	109,000	4,277	150	5,715	4,530	27,252	18,170
	HI	238,400	27,258,000	40,900	136,000,000	17,030	4,233,000	45,420	98,436,000
PARAMETER, MG/L									
BOD	LO	1.4	2	1.0	0	10.8	0	1.2	0
	HI	22	18	48	344	11.7	6	3.0	30
COD	LO	10	36	2.0	0	2.0	0	240	2
	HI	102	436	76	440	157	784	1,235	306
CHROMIUM	LO	0.02	10	0.02	0.05	.02	0.001	0.12	0.045
	HI	5	120	0.1	2.168	.02	1.5	0.37	40
COPPER	LO	0.02	63	0.02	0.006	.02	0	0.16	.009
	HI	0.7	1,740	2.6	3.09	.19	0.3	0.2	100
IRON	LO	0.5	60	0.02	0.015	.03	0.03	6.2	0.001
	HI	1.6	1,160	10.4	37.5	1.4	0.3	76.0	2,100
NICKEL	LO	0.03	80	0.03	0.007	.03	0	0.03	0.01
	HI	0.04	150	0.25	0.56	.03	0.13	0.24	10
PHOSPHATE	LO	0.1	0.1	0.05	0.1	.05	0.01	0.02	0
	HI	3	18	14.0	87.2	19.8	29	3.4	0.24
TDS	LO	886	150	0.16	2	118	5	388	83
	HI	5,111	32,700	23,000	35,235	1,405	26,006	1,894	32,423
TSS	LO	3	2	1.0	0	2.7	0	1,144	4
	HI	59	220	1,780	300	31	300	1,651	236
TS	LO	889	750	0.16	15	125	5	1,532	35
	HI	5,170	32,700	1,958	36,237	1407.7	26,077	3,545	32,412
ZINC	LO	0.1	0.3	0.02	0	.01	0.1	0.03	0
	HI	1.5	3,000	0.44	4.5	.05	1.2	0.55	0.52

SECTION VI

CONSIDERATION OF POLLUTANT PARAMETERS

INTRODUCTION

Aqueous pollutants originating from steam electric power generating facilities are considered in this section to determine if they interfere with the operation of publicly-owned treatment works (POTW) and if they are susceptible to treatment by such treatment works.

THE CONSIDERATION OF POLLUTANT PARAMETERS

Pollutants were considered on the basis of their potential for interference with the operation of treatment works and on the basis of their treatability by such works, as follows:

- Potential interference with POTW

  The pollutant may impair the activity of biological treatment systems by either causing the death of some or all of the microorganisms that are essential to the operation of the POTW, or impairing the activity of these microorganisms so that their waste-consuming efficiency is lowered. Examples of treatment units that may be adversely affected by pollutants are: trickling filters, activated sludge units, anaerobic digesters, and nitrification units. Additionally, consideration is given to other characteristics of power plant discharges which would interfere with other parts of the POTW such as transport piping.

- Susceptibility to treatment

  Pollutants were considered that are not removed or that are removed inadequately by treatment works. For those pollutants which are partially removed, the problem of disposing the sludge that contains such pollutants is also considered.

The remainder of this section is devoted to a discussion of the properties of the pollutants considered, the effect of these pollutants on treatment works, and their treatability in treatment works.

PROPERTIES OF POLLUTANT PARAMETERS CONSIDERED

Acidity and Alkalinity - pH

Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not a linear or direct measure of either, however, it may be properly used as a surrogate to control both excess acidity and excess alkalinity in water. The term pH is used to describe the hydrogen ion - hydroxyl ion balance in water. Technically, pH is related to the hydrogen ion concentration or activity present in a given solution. pH numbers are the negative logarithm of the hydrogen ion concentration. A pH of 7 indicates neutrality or a balance between free hydrogen and free hydroxyl ions. Solutions with a pH above 7 indicate that the solution is alkaline, while a pH below 7 indicates that the solution is acidic. Knowledge of the pH of water or wastewater is useful in determining necessary measures for corrosion control, pollution control, and disinfection. Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures such as iron, copper, zinc, cadmium, and lead. Low pH waters not only tend to dissolve metals from structures and fixtures but also tend to redissolve or leach metals from sludges and bottom sediments. The hydrogen ion concentration can affect the "taste" of the water and at a low pH, water tastes "sour."

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. For example, metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. Similarly, the toxicity of ammonia is a function of pH. The bactericidal effect of chlorine in most cases is less as the pH increases, and it is economically advantageous to keep the pH close to 7.

Most bacteria (and other protists) that are essential to the operation of a biological treatment system cannot bear pH levels above 9.5 or below 5.0. The pH range for optimum growth generally lies between 6.5 to 7.5. Depending on the volume of a particular waste and the acidity or alkalinity of the waste in the treatment unit, an incoming waste of extreme pH could have a substantially adverse effect on a treatment unit.

Acidity. Acidity is defined as the quantitative ability of a water to neutralize hydroxyl ions. It is usually expressed as the calcium carbonate equivalent of the hydroxyl ions neutralized. Acidity should not be confused with pH value. Acidity is the quantity of hydrogen ions which may be released to react with or neutralize hydroxyl ions while pH is a measure of the free hydrogen ions in a solution at the instant the pH measurement is made. A property of many chemicals, called buffering, may hold hydrogen ions in solution from being in the free state and being measured as pH. The bond of most buffers is rather weak and hydrogen ions tend to be released from the buffer as needed to maintain a fixed pH value.

Highly acid waters are corrosive to metals, concrete, and living organisms, exhibiting the pollutional characteristics outlined above for low pH waters. Depending on buffering capacity, water may have a higher total acidity at pH values of 6.0 than other waters with a pH value of 4.0.

Highly acid wastes can exhibit the same detrimental effects on microorganisms as wastes of low pH. The acidity of an incoming waste is particularly important in the operation of anaerobic digesters, where the pH for optimum operation is 6.6 to 7.6 An incoming waste of high acidity that causes the pH of an anaerobic system to drop below 6.2 will severely upset the operation of the unit. Wastes of high acidity are also corrosive to the metals and concrete that make up the structure of any treatment unit.

Alkalinity. Alkalinity is defined as the ability of a water to neutralize hydrogen ions. It is usually expressed as the calcium carbonate equivalent of the hydrogen ions neutralized.

Alkalinity is commonly caused by the presence of carbonates, bicarbonates, hydroxides, and to a lesser extent borates, silicates, phophates, and organic substances. Because of the nature of the chemicals causing alkalinity, and the buffering capacity of carbon dioxide in water, very high pH values are seldom found in natural waters.

Excess alkalinity, as exhibited in a high pH value, may make water corrosive to certain metals, detrimental to most natural organic materials, and toxic to living organisms.

Ammonia is more irritating at higher pH. The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

A waste of high alkalinity can interfere with the operation of a treatment unit, causing the death of microorganisms and the corrosion of structural materials.

Oil and Grease

Because of widespread use, oil and grease occurs often in wastewater streams. These oily wastes may be classified as follows:

- Light Hydrocarbons. These include light fuels such as gasoline, kerosene, and jet fuel, and miscellaneous solvents used for industrial processing, degreasing, or cleaning purposes. The presence of these hydrocarbons may make the removal of other heavier oily wastes more difficult.
- Heavy Hydrocarbons, Fuels, and Tars. These include the crude oils, diesel oils, #6 fuel oil, residual oils, shop oils, and in some cases, asphalt and road tar.
- Lubricants and Cutting Fluids. These generally fall into two classes: non-emulsifiable oils such as lubricating oils and greases, and emulsifiable oils such as water soluble oils, rolling oils, cutting oils, and drawing compounds. Emulsifiable oils may contain fat, soap or various other additives.

These compounds can settle or float and may exist as solids or liquids depending upon factors such as method of use, production process, and temperature of wastewater.

Oil and grease even in small quantities causes troublesome taste and odor problems. Scum lines from these agents are formed on water treatment basin walls and other containers. Fish and waterfowl are adversely affected by oils in their habitat. Oil emulsions may adhere to the gills of fish causing suffocation, and the flesh of fish is tainted when microorganisms that were exposed to waste oil are eaten. Deposition of oil in the bottom sediments of water can serve to inhibit normal benthic growth. Oil and grease exhibit an oxygen demand.

Levels of oil and grease which are toxic to aquatic organisms vary greatly, depending on the type and the species susceptibility. However, it has been reported that crude oil in concentrations as low as 0.3 mg/l is extremely toxic to freshwater fish. It has been recommended that public water supply sources be essentially free from oil and grease.

Oil and grease in quantities of 100 l/sq km (10 gallons/sq mile) show up as a sheen on the surface of a body of water. The presence of oil slicks prevent the full aesthetic enjoyment of water. The presence of oil in water can also increase the toxicity of other substances being discharged into the receiving bodies of water.

Oil and grease can cause problems with scum formation in wet wells and clarifiers. Mineral oils in particular can coat solid particles that are present in wastes. The particles hinder biological activity and increase maintenance problems. Free oil (as measured by CCl_4 extraction) has reportedly interfered with aerobic biological treatment at concentrations of 50 to 100 mg/l (15).

Oxygen Demand (BOD and COD)

Organic and some inorganic compounds can cause an oxygen demand to be exerted in a receiving body of water. Indigenous microorganisms utilize the organic wastes as an energy source and oxidize the organic matter. In doing so their natural respiratory activity will utilize the dissolved oxygen.

Biochemical oxygen demand (BOD). BOD is the quantity of oxygen required for the biological and chemical oxidation of waterborne substances under ambient or test conditions. Materials which may contribute to the BOD include: carbonaceous organic materials usable as a food source by aerobic organisms; oxidizable nitrogen derived from nitrites, ammonia and organic nitrogen compounds which serve as food for specific bacteria, and certain chemically oxidizable materials such as ferrous iron, sulfides, sulfite, etc. which will react with dissolved oxygen or are metabolized by bacteria. In most industrial and municipal wastewaters, the BOD derives principally from organic materials and from ammonia (which is itself derived from animal or vegetable matter).

The BOD of a waste exerts an adverse effect upon the dissolved oxygen resources of a body of water by reducing the oxygen available to fish, plant life, and other aquatic species. Conditions can be reached where all of the dissolved oxygen in the water is utilized, resulting in anaerobic conditions and the production of undesirable gases such as hydrogen sulfide and methane. The reduction of dissolved oxygen can be detrimental to fish populations, fish growth rate, and organisms used as fish food. A total lack of oxygen due to the exertion of an excessive BOD can result in the death of all aerobic aquatic inhabitants in the affected area.

Water with a high BOD indicates the presence of decomposing organic matter and an associated increase in bacterial concentrations that degrade its quality and potential uses.

A by-product of high BOD concentrations can be increased algal concentrations and blooms which result from decomposition of the organic matter and which form the basis of algal populations.

The BOD5 (5-day BOD) test is used widely to estimate the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into receiving streams. The test is an important one in water pollution control activities, to evaluate the design and efficiencies of wastewater treatment works, and to indicate the state of purification or pollution of receiving bodies of water.

Complete biochemical oxidation of a given waste may require a period of incubation too long for practical analytical test purposes. For this reason, the five day period has been accepted as standard, and the test results have been designated as BOD5. Specific chemical test methods are not readily available for measuring the quantity of many degradable substances and their reaction products. Reliance in such cases is placed on the collective parameter, BOD5 which measures the weight of dissolved oxygen utilized by microorganisms as they oxidize or transform the gross mixture of chemical compounds in the wastewater. The biochemical reactions involved in the oxidation of carbon compounds are related to the period of incubation. The five-day BOD normally measures only 60 to 80 percent of the carbonaceous biochemical oxygen demand of the sample, and for many purposes this is a reasonable parameter.

Additionally, it can be used to estimate the gross quantity of oxidizable organic matter.

The BOD5 test is essentially a bioassay procedure which provides an estimate of the oxygen consumed by microorganisms utilizing the degradable matter present in a waste under conditions that are representative of those that are likely to occur in nature. Standard conditions of time, temperature, suggested microbial seed, and dilution water for the wastes have been defined and are incorporated in the standard analytical procedure. Through the use of this procedure, the oxygen demand of diverse wastes can be compared and evaluated for pollution potential and to some extent for treatability by biological treatment processes.

Because the BOD test is a bioassay procedure, it is important that the environmental conditions of the test be suitable for the microorganisms to function in an uninhibited manner at all times. This means that toxic substances must be absent and that the necessary nutrients, such as nitrogen, phosphorous, and trace elements, must be present.

Chemical Oxygen Demand (COD). COD is a purely chemical oxidation test devised as an alternate method of estimating the total oxygen demand of a wastewater. Since the method relies on the oxidation-reduction system of chemical analyses rather than on biological factors, it is more precise, accurate, and rapid than the BOD test. The COD test is widely used to estimate the total oxygen demand (ultimate rather than 5-day BOD) to oxidize the compounds in wastewater. It is based on the fact that organic compounds, with a few exceptions, can be oxidized by strong chemical oxidizing agents under acid conditions with the assistance of certain inorganic catalysts.

The COD test measures the oxygen demand of compounds that are biologically degradable and of many that are not. Pollutants which are measured by the BOD_5 test will be measured by the COD test. In addition, pollutants which are more resistant to biological oxidation will also be measured as COD. COD is a more inclusive measure of oxygen demand than is BOD_5 and will result in higher oxygen demand values than will the BOD_5 test.

The compounds which are more resistant to biological oxidation are becoming of greater and greater concern not only because of their slow but continuing oxygen demand on the resources of the receiving water, but also because of their potential health effects on aquatic life and humans.

Many of these compounds result from industrial discharges and some have now been found to have carcinogenic, mutagenic and similar adverse effects, either singly or in combination. Concern about these compounds has increased as a result of demonstrations that their long life in receiving waters - the result of a slow biochemical oxidation rate - allows them to contaminate downstream water intakes. The commonly used systems of water purification are not effective in removing these types of materials and disinfection such as chlorination may convert them into even more hazardous materials.

Thus, the COD test measures organic matter which exerts an oxygen demand and which may affect the health of people. It is a useful analytical tool for pollution control activities. It provides a more rapid measurement of the oxygen demand and an estimate of organic compounds which are not measured in the BOD_5 test.

Total Suspended Solids (TSS)

Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These solids discharged with man's waste may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynethic activity of aquatic plants.

Chromium (Cr)

Chromium is an elemental metal usually found as a chromite ($FeCr_2O_4$). The metal is normally processed by reducing the oxide with aluminum.

Chromium and its compounds are used extensively throughout industry. It is used to harden steel and as an ingredient in other useful alloys. Chromium is also used in the electroplating industry as an ornamental and corrosion resistant plating on steel and can be used in pigments and as a pickling acid (chromic acid).

The two most prevalent chromium forms found in industry wastewaters are hexavalent and trivalent chromium. Chromic acid used in industry is a hexavalent chromium compound which is partially reduced to the trivalent form during use. Chromium can exist as either trivalent or hexavalent compounds in raw waste streams, but hexavalent chromium predominates at the conditions found in most wastes. Hexavalent chromium treatment involves reduction to the trivalent form prior to removal of chromium from the waste stream as a hydroxide precipitate.

Chromium, in its various valence states, is hazardous to man. It can produce lung tumors when inhaled and induces skin sensitizations. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Levels of chromate ions that have no effect on man appear to be so low as to prohibit determination to date. The recommendation for public water supplies is that such supplies contain no more than 0.05 mg/l total chromium.

The toxicity of chromium salts to fish and other aquatic life varies widely with the species, temperature, pH, valence of the chromium, and synergistic or antagonistic effects, especially that of hard water. Studies have shown that trivalent chromium is more toxic to fish of some types than hexavalent chromium. Other studies have shown opposite effects. Fish food organisms and other lower forms of aquatic life are extremely sensitive to chromium and it also inhibits the growth of algae. Therefore, both hexavalent and trivalent chromium must be considered harmful to particular fish or organisms.

Hexavalent chromium has been shown to interfere with the operation of activated sludge systems and anaerobic digesters (22) and nitrification units (15). Slug doses of hexavalent chromium of 500 mg/l to activated sludge systems have been shown to reduce BOD removal efficiency by 11 percent and COD removal efficiency by 13 percent. for periods as long as 32 hours. Slug doses of 300 mg/l to anaerobic digesters have caused gas production to cease for seven days, and doses of 500 mg/l have ceased gas production permanently. The nitrification process is severely affected at Cr+6 concentrations in raw sewage on the order of 2 mg/l to 5 mg/l. The effects on these systems can be multiplied by the presence of iron, copper, and high acidity, since these constituents exert synergistic effects with chromium (16).

Depending on the influent concentration, significant amounts of Cr+6 can pass through activated sludge systems; the removal efficiency has been reported to be as low as 17 percent at influent Cr+6 concentrations of 50.0 mg/l, but as high as 78 percent at concentrations of 0.5 mg/l (22).

Copper (Cu)

Copper is an elemental metal that is sometimes found free in nature and is found in many minerals such as cuprite, malachite, azurite, chalcopyrite, and bornite. Copper is obtained from these ores by smelting, leaching, and electrolysis. Significant industrial uses are in the plating, electrical, plumbing, and heating equipment industries. Copper is also commonly used with other minerals as an insecticide and fungicide.

Traces of copper are found in all forms of plant and animal life, and it is an essential trace element for nutrition. Copper is not considered to be a cumulative systemic poison for humans as it is readily excreted by the body, but it can cause symptoms of gastroenteritis, with nausea and intestinal irritations, at relatively low dosages. The limiting factor in domestic water supplies is taste. Threshold concentrations for taste have been generally reported in the range of 1.0 to 2.0 mg/l of copper while concentrations of 5 to 7.5 mg/l have made water completely undrinkable. It has been recommended that the copper in public water supply sources not exceed 1 mg/l.

Copper salts cause undersirable color reactions in the food industry and cause pitting when deposited on some other metals such as aluminum and galvanized steel. The textile industry is affected when copper salts are present in water used for processing of fabrics. Irrigation waters containing more than minute quantities of copper can be detrimental to certain crops. The toxicity of copper to aquatic organisms varies significantly, not only with the species, but also with the physical and chemical characteristics of the water, including temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts may be reduced by the precipitation of copper carbonate or other insoluble compounds. The sulfates of copper and zinc and of copper and cadmium are synergistic in their toxic effect on fish.

Copper concentrations less than 1 mg/l have been reported to be toxic, particularly in soft water, to many kinds of fish, crustaceans, mollusks, insects, phytoplankon and zooplankton. Concentrations of copper, for example, are detrimental to some oysters above 0.1 mg/l. Oysters, cultured in seawater containing 0.13 to 0.5 mg/l of copper, deposit the metal in their bodies and become unfit as a food substance.

The toxic effects of copper are compounded when certain other metals are present. Copper and zinc have been reported to be five times as toxic when combined than would be expected considering the toxicity of each metal separately. Increased toxicological effects of a similar magnitude have been noted between copper and cadmium, and other synergistic toxic effects of copper have been observed when mercury or phosphates are present. Conversely, sulfide, high pH, and certain chelating agents (such as EDTA) have been reported to be antagonistic with copper (16).

Copper, as well as most metals, is generally not susceptable to treatment by biological treatment processes at POTW. Research has shown that up to half of the input metal will pass through the treatment plant, with about 30 to 50 percent of the copper which passes through the plant appearing in the soluble state. Digestion has been impaired by copper continuously fed at 10 mg/l, and slug doses of copper at 50 mg/l for four hours in an unacclimated system have resulted in greatly decreased efficiencies of treatment plants for up to 100 hours.

The copper that is removed from the influent stream by the POTW is absorbed on the sludge, or it appears in the sludge as the hydroxide of the metal. Experimental data shows that when dried sludge is spread over tillable land, the copper tends to remain in place down to the depth of tillage, except for that copper that is taken up by plants grown in the soil. Copper tends to concentrate in the roots of plants, and has shown little tendency to migrate to other parts of the plant. In most cases, the concentration of copper in plants will kill the plant before it has reached a high enough concentration to evidence harm in animals that may eat the plants, although it is reported that copper concentrated in plants has resulted in fatalities among sheep.

Cyanide (CN)

Cyanide is a compound that is widely used in industry primarily as sodium cyanide (NaCN) or hydrocyanic acid (HCN). The major use of cyanides is in the electroplating industry where cyanide baths are used to hold ions such as zinc and cadmium in solution. Cyanides in various compounds are also used in steel plants, chemical plants, photographic processing, textile dying, and ore processing.

Of all the cyanides, hydrogen cyanide (HCN) is probably the most acutely lethal compound. HCN dissociates in water to hydrogen ions and cyanide ions in a pH dependent reaction. The cyanide ion is less acutely lethal than HCN. The relationship of pH to HCN shows that as the pH is lowered to below seven there is less than one percent of the cyanide molecules in the form of the CN ion and the rest is present as HCN. When the pH is increased to 8, 9, and 10, the percentage of cyanide present as CN ion is 6.7, 42, and 87 percent, respectively. The toxicity of cyanides is also increased by increases in temperature. A rise of 10°C produced a two-to threefold increase in the rate of the lethal action of cyanide.

In the body, the CN ion, except for a small portion exhaled, is rapidly changed into a relatively non-toxic complex (thiocyanate) in the liver and eliminated in the urine. There is no evidence that the CN ion is stored in the body. The safe ingested limit of cyanide has been estimated to be something less than 18 mg/day, part of which comes from normal environment and industrial exposure. The average fatal dose of HCN by ingestion by man is 50 to 60 mg. It has been recommended that a limit of 0.2 mg/l cyanide not be exceeded in public water supply sources.

The harmful effects of the cyanides on aquatic life is affected by the pH, temperature, dissolved oxygen content, and the concentration of minerals in the water. The biochemical degradation of cyanide is not affected by temperature in the range of 10°C to 35°C while the toxicity of HCN is increased at higher temperatures.

On lower forms of life and organisms, cyanide does not seem to be as toxic as it is toward fish. The organisms that digest BOD were found to be inhibited at 60 mg/l although the effect is more one of delay in exertion of BOD than total reduction.

Certain metals such as nickel may form complexes with cyanide to reduce lethality, especially at higher pH values. On the other hand, zinc and cadmium cyanide complexes may be exceedingly toxic.

Research has shown that concentrations of 1.0 to 2.0 mg/l of cyanide (as HCN) in influent sewage adversely affect the performance of activated sludge units and anaerobic digesters, and 2.0 mg/l of cyanide inhibits the nitrification process. The quality of trickling filter effluent has been reported to be severely affected at influent cyanide concentrations of 30 mg/l (15).

Iron (Fe)

Iron is an abundant metal found in the earth's crust. The most common iron ore is hematite from which iron is obtained by reduction with carbon. Other forms of commercial ores are magnetite and taconite. Pure iron is not often found in commercial use, but it is usually alloyed with other metals and minerals, the most common being carbon.

Iron is the basic element in the production of steel and steel alloys. Iron with carbon is used for casting of major parts of machines and it can be machined, cast, formed, and welded. Ferrous iron is used in paints, while powdered iron can be sintered and used in powder metallurgy. Iron compounds are also used to precipitate other metals and undesirable minerals from industrial wastewater streams.

Iron is chemically reactive and corrodes rapidly in the presence of moist air and at elevated temperatures. In water and in the presence of oxygen, the resulting products of iron corrosion may be pollutants in water. Natural pollution occurs from the leaching of soluble iron salts from soil and rocks and is increased by industrial wastewater from pickling baths and other solutions containing iron salts.

Corrosion products of iron in water cause staining of porcelain fixtures, and ferric iron combines with tannin to produce a dark violet color. The presence of excessive iron in water discourages cows from drinking and, thus reduces milk production. High concentrations of ferric and ferrous irons in water kill most fish introduced to the solution within a few hours. The killing action is attributed to coatings of iron hydroxide precipitates on the gills. Iron-oxidizing bacteria are dependent on iron in water for growth. These bacteria form slimes that can affect the aesthetic values of bodies of water and cause stoppage of flows in pipes.

Iron is an essential nutrient and micronutrient for all forms of growth. Drinking water standards in the U.S. have set a recommended limit of 0.3 mg/l of iron in domestic water supplies based not on physiological considerations, but rather on aesthetic and taste considerations.

Iron has no effect on the activated sludge process except at very high concentrations (on the order of 1000 mg/l). The effect of iron on the sludge digestion process has been reported to be much greater - iron levels above 5 mg/l in digesters have caused interference with the process, due to the release of acidity when the iron is hydrolyzed. These effects may be magnified by the synergistic effect of chromium on iron, or decreased by the antagonistic effects of sulfide, cyanide, and high pH on irons (16).

Nickel (Ni)

Elemental nickel is seldom found in nature in the pure state. Nickel is obtained commercially from pentlendite and pyrrhotite. It is a relatively plentiful element and is widely distributed throughout the earth's crust. It occurs in marine organisms and is found in the oceans. Depending on the dose, the organism involved, and the type of compound involved, nickel may be beneficial or toxic. Pure nickel is not soluble in water but many of its salts are very soluble.

The toxicity of nickel to man is believed to be very low and systemic poisoning of human beings by nickel or nickel salts is almost unknown. Nickel salts have caused the inhibition of the biochemical oxidation of sewage. They also caused a 50 percent reduction in the oxygen utilization from synthetic sewage in concentrations of 3.6 to 27 mg/l of various nickel salts.

Nickel is extremely toxic to citrus plants. It is found in many soils in California, generally in insoluble form, but excessive acidification of such soil may render it soluble, causing severe injury to or the death of plants. Many experiments with plants in solution cultures have shown that nickel at 0.5 to 1.0 mg/l is inhibitory to growth.

Nickel salts can kill fish at very low concentrations. However, it has been found to be less toxic to some fish than copper, zinc, and iron. Data for the fathead minnow show death occurring in the range of 5 to 43 mg/l depending on the alkalinity of the water.

Nickel is present in coastal and open ocean with concentrations in the range of 0.1 to 6.0 mg/l, although the most common values are 2 to 3 mg/l. Marine animals contain up to 400 mg/l, and marine plants contain up to 3,000 mg/l. The lethal limit of nickel to some marine fish has been reported as low as 0.8 ppm. Concentrations of 13.1 mg/l have been reported to cause a 50 percent reduction of the photosynthetic activity in the giant kelp (Macrocystic pyrifera) in 96 hours, and a low concentration was found to kill oyster eggs.

Nickel can inhibit the operation of activated sludge units and nitrification units. Up to a five percent decrease in the BOD removal efficiency of activated sludge units has been reported at nickel influent concentrations of 2.5 to 10.0 mg/l. Slug doses of nickel of 200 mg/l to activated sludge units have been reported to seriously reduce treatment efficiency (22). Severe inhibition of the nitrification process has been reported at nickel influent concentrations of 0.5 mg/l (15).

Significant amounts of nickel can pass through treatment units - the activated sludge process has been reported to be only approximately 30 percent efficient in the removal of nickel.

Phosphorus (P)

Phosphorus occurs in natural waters and in wastewaters in the form of various types of phosphates. These forms are commonly classified into orthophosphates, condensed phosphates (pyro-, meta-, and polyphosphorus), and originally bound phosphates. These may occur in the soluble form, in particles of detritus, or in the bodies of aquatic organisms.

The various forms of phosphates find their way into wastewaters from a variety of industrial, residential, and commercial sources. Small amounts of certain condensed phosphates are added to some water supplies in the course of potable water treatment. Large quantities of the same compounds may be added when the water is used for laundering or other cleaning since these materials are major constituents of many commercial cleaning preparations. Phosphate coating of metals is another major source of phosphates in certain industrial effluents.

The increasing problem of the growth of algae in streams and lakes appears to be associated with the increasing presence of certain dissolved nutrients, chief among which is phosphorus. Phosphorus is an element which is essential to the growth of organisms and it can often be the nutrient that limits the aquatic growth that a body of water can support. In instances where phosphorus is a growth limiting nutrient, the discharge of sewage, agricultural drainage, or certain industrial wastes to a receiving water may stimulate the growth, in nuisance quantities, of photosynthetic aquatic microorganisms and macroorganisms.

The increase in organic matter production by algae and plants in a lake undergoing eutrophication has ramifications throughout the aquatic ecosystem. Greater demand is placed on the dissolved oxygen in the water as the organic matter decomposes at the termination of the life cycles. Because of this process, the deeper waters of the lake may become entirely depleted of oxygen, thereby destroying fish habitats and leading to the elimination of desirable species. The settling of particulate matter from the productive upper layers changes the character of the bottom mud, also leading to the replacement of certain species by less desirable organisms. Of great importance is the fact that nutrients inadvertently introduced to a lake are, for the most part, trapped there and recycled in accelerated biological processes. Consequently, the damage done to a lake in a relatively short time requires a many fold increase in time for recovery of the lake.

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Zinc (Zn)

Occurring abundantly in rocks and ores, zinc is readily refined into a stable pure metal and is used extensively for galvanizing, in alloys, for electrical purposes, in printing plates, for dye manufacture and for dyeing processes, and for many other industrial purposes. Zinc salts are used in paint pigments, cosmetics, pharmaceuticals, dyes, insecticides, and other products too numerous to list herein. Many of these salts (e.g., zinc chloride and zinc sulfate) are highly soluble in water; hence it is to be expected that zinc might occur in many industrial wastes. On the other hand, some zinc salts (zinc carbonate, zinc oxide, zinc sulfide) are insoluble in water and consequently it is to be expected that some zinc will precipitate and be removed readily in most natural waters.

In zinc mining areas, zinc has been found in waters in concentrations as high as 50 mg/l and, in effluents from metal-plating works and small-arms ammunition plants, it may occur in significant concentrations. In most surface and ground waters, it is present only in trace amounts. There is some evidence that zinc irons are adsorbed strongly and permanently on silt, resulting in inactivation of the zinc.

Concentrations of zinc in excess of 5 mg/l in raw water used for drinking water supplies cause an undesirable taste which persists through conventional treatment. Zinc can have an adverse effect on man and animals at high concentrations.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/l have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucous that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison. The sensitivity of fish to zinc varies with species, age and condition, as well as with the physical and chemical characteristics of the water. Some acclimatization to the presence of zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated to zinc-free water (after 4 to 6 hours of exposure to zinc) may die 48 hours later. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, but the presence of calcium or hardness may decrease the relative toxicity.

Observed values for the distribution of zinc in ocean waters vary widely. The major concern with zinc compounds in marine waters is not one of acute toxicity, but rather of the long-term sublethal effects of the metallic compounds and complexes. From an acute toxicity point of view, invertebrate marine animals seem to be the most sensitive organisms tested. The growth of the sea urchin, for example, has been retarded by as little as 30 ug/l of zinc.

Zinc is readily taken up and translocated within plants. The activity of zinc is most profound in acid soils and decreases in the presence of large amounts of phosphates, as would be found in sludges from POTW. For each unit increase in the pH, there is a hundredfold decrease in the toxicity of zinc. In plants the poisoning mechanism is iron deficiency, and to avoid this, lime must be added to the soil to maintain soil pH above 6.0. Generally, zinc will kill the plants before reaching concentrations harmful to animals in the plants.

Dissolved zinc is generally not susceptible to treatment by biological treatment processes at POTW. In slug doses, and particularly in the presence of copper, dissolved zinc can interfere with or seriously disrupt the operation of POTW using biological processes by reducing overall removal efficiencies, largely as a result of the toxicity of the metal to biological organisms. However, zinc solids (in the form of hydroxides or sulfides) do not appear to interfere with biological treatment processes on the basis of available data. Such solids accumulate in the sludge, where subsequent effects depend on the sludge disposal method.

Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a family of partially or wholly chlorinated isomers of biphenyl. The commercial mixtures generally contain 40 to 60 percent chlorine with as many as 50 different detectable isomers present. The PCB mixture is a colorless and viscous fluid, relatively insoluble in water, that can withstand very high temperatures without degradation. PCB's do not conduct electricity, and the more highly chlorinated isomers are not readily degraded in the environment.

PCBs are used in paints, inks, and plastics. They are also found in hydraulic systems, in transformers and capacitors, and in the wastes from the reprocessing of certain papers.

The major uses of PCBs can be grouped into three major categories: open uses, partially closed system uses, and closed system uses. Open uses include paints, inks, plastics, and paper coatings. The PCBs in all of these products contact with the environment and can be leached out by water. The so-called carbonless carbon paper contains

PCBs in the encapsulated ink and is claimed to be responsible for the PCBs found extensively in recycled paper. PCBs have been used as plasticizers in polyvinyl chloride (PVC) and chlorinated rubbers.

Uses of PCBs in partially closed systems include the working fluid in heat exchangers and hydraulic systems. These systems have a potential for leakage of the PCB fluid either during use or after being discarded.

The electric industry is the single major consumer of PCBs mainly in a closed loop system in transformers and capacitors. PCBs are ideal for use in large transformers and power capcitors, since they are non-flammable and do not conduct electricity, but still transfer heat well. The fluid is generally sealed into the unit to prevent loss, but leakage may occur from some transformers through gaskets or broken oil level viewing glasses. Release of PCBs into the environment may also occur during the drainage and replacement of oil in defective transformers, or if old or defective capacitors are disposed of in landfills and broken while being buried. Transformers and capacitors account for about 63 percent of all PCB use.

Agreement is not universal on exactly how PCBs are released into the environment or in what quantities. Analyses of water samples from 30 major tributaries to the Great Lakes indicate widespread contamination, with 71 percent of all samples having detectable concentrations (greater than 10 parts per trillion). PCBs have been found in all organisms analyzed from the north and south Atlantic, even in animals living under 11,000 feet of water. It is reported that one-third of the human tissue sampled in the United States contains more than one part per million (ppm) of PCBs.

Once in the environment, PCBs appear to persist for a long time. Evidence for this can be seen in the fact that in most areas of the continent and through out the Atlantic Ocean more PCB than DDT is found in the animals, even though three times more DDT is produced each year and all of it is discharged directly into the environment. Based on present available data, it seems safe to assume the PCBs are present in varying concentrations in every species of wildlife on earth.

Liver damage is a common effect of PCBs on all species, while the occurrence of edema, skin lesions, and reproductive failure is species-specific. Hatchability of eggs is noticeably decreased by exposure to PCBs. PCBs have been shown to produce lethal and sublethal effects on fish and animals, including reduced reproduction of the species and abnormal young.

PCBs may be removed by up to 70 percent or more from domestic wastewaters during biological treatment (22). However, PCBs appear to simply accumulate unchanged in treatment tank sludges, and are not biodegraded or converted to other more readily degradable substances during treatment (23). Disposal of treatment sludges in landfills could then release PCBs into the environment once again. There is some evidence, however, that PCBs are destroyed during incineration of sewage sludge (24).

Ethylenediamine Tetracetic Acid (EDTA)

No definitive information on the toxicity or treatability of EDTA in biological treatment systems is available to EPA at the present time.

SECTION VII

TREATMENT AND CONTROL TECHNOLOGY

Introduction

Treatment and control technologies for potential pollutants discharged from steam electric power generating plants discharging to publicly-owned treatment works (POTW) are outlined in this section. In-process controls discussed include those techniques which are normally used by the industry or by industries employing similar processes. Such controls include process modifications, materials substitution, raw materials and products recovery, water conservation and wastewater reuse, and general good housekeeping practices.

Wastewater effluents discharged to publicly-owned treatment facilities are sometimes treated by end-of-process physical or chemical systems to remove pollutants which can upset operation of the POTW or which may be treated inadequately. Such treatment methods are numerous, but they generally fall into one of three broad categories in accordance with their process objectives. These include pH control, removal of dissolved materials, and separation of phases.

Of the twenty-three plants surveyed only eight provide end-of-pipe treatment to their waste, before discharging it to POTW. The extent of treatment applied varies in accordance with the local requirements for discharge limitations. Most of the plants use retention ponds to equalize the flow to POTWs. These ponds also serve as sedimentation basins for partial removal of suspended solids by gravity settling and are sometimes equipped with skimming devices to remove floating oil. A detailed description of end-of-pipe treatment techniques used is presented in Section V of this report.

END-OF-PIPE TREATMENT TECHNOLOGY

Treatment Technologies Available

If a pollutant in a waste stream is not acceptable for discharge to the publicly-owned treatment plant, end-of-pipe treatment must be provided to remove the pollutant or reduce it to allowable limits. Only a few existing plants discharging into POTW provide end-of-pipe treatment. Yet, basic technology is available to reduce nearly all of the pollutants produced by steam electric generating plants. For certain pollutants, in-plant controls are probably the preferred control strategy. This technology is shown in

Tables VII-1 and VII-2. Table VII-1 lists potential dissolved matter removal methods and Table VII-2 provides a similar list of solid liquid separation processes. Most of the processes listed are in use for treatment of steam electric or other industrial or municipal water and wastewaters.

TREATMENT OF MAJOR POLLUTANTS

Available technology and efficiency of their removal for major pollutants are shown in Table VII-3. These are based on data obtained from several different industries who discharge pollutants similar to those observed in this industry. The following is a brief discussion of the technologies associated with removal of pollutants from the power plant.

Total Dissolved Solids. Removal of total dissolved solids (TDS) from wastewaters is one of the more difficult and more expensive waste treatment procedures. Where TDS result from heavy metal or hardness ions, reduction can be achieved by chemical precipitation methods; however, where dissolved solids are present as sodium, calcium, or potassium compounds, then TDS reduction requires more specialized treatment, such as reverse osmosis, electrodialysis, distillation, and ion exchange.

Total Suspended Solids. Suspended solids removal can be achieved by sedimentation and filtration operations. Sedimentation lagoons are commonly used at steam electric power plants. Some plants employed configured tanks. Tanks can be used where space limitations are important. Tanks constructed for solids removal usually have built-in facilities for continuous or intermittent sludge removal. Designs based on maximum flow anticipated can provide the best performance. Equalization can be provided to regulate flow. The retention time required is related to the particle characteristics.

Oil and Grease. Certain preventative measures can be applied to prevent spillage of oil and the entrance of oil into the plant drainage system. Flotation is efficient in removing emulsified oil and requires minimum space. It can be used without chemical addition, but demulsifiers and coagulants can improve performance in some cases. Whenever possible, primary separation facilities should be employed to remove free oil and solids before the water enters the flotation unit. Multistage units are more effective than single-stage units. Partial recycle units are more effective than full-pressure units. Oil removal facilities including single-cell flotation can achieve effluent oil and

Table VII-1. END-OF-PIPE TREATMENT METHODS

Method	objectives	Chemicals or equipment used	Process requirements	Efficiency of removal	Advantages	Limitations	Required maintenance	Demonstration status
Neutralization	pH adjustment, usually to within the range of 6-9	acid or base as required, usually sulfuric acid and lime			1-operates at ambient environment 2-well suited for automatic control 3-high rate of reactions	1-may cause scaling in tanks and conduits 2-produces large quantities of sludge 3-may generate toxic by-products	periodic removal of sludge	practiced extensively by industry
Chemical reduction	reduction of hexavalent chromium to trivalent chromium	sulfur dioxide, sodium bisulfite, sodium metabisulfite, ferrous salts	pH range of 2-3	99.7%	1-operates at ambient environment 2-well suited to automatic control	1-requires careful pH control 2-presence of oxidants (oxygen, ferric ion) increases required dose of the reducing agent 3-Sulfur dioxide is toxic and corrosive	periodic removal of sludge	practiced extensively by industry
Precipitation	removal of ions by forming slightly soluble salts	lime, hydrogen sulfide, organic precipitants, soda ash	optimum pH depends on the ions to be removed	copper-96.6% nickel-91.7% chromium-98.8% zinc-99.7% phosphate-93.6%	1-operates at ambient environment 2-well suited to automatic control	1-requires careful pH control 2-may require more than a single step to remove a mixture of ions 3-presence of chelating agents (i.e., cyanide) increases the solubility of many metals	periodic removal of sludge	practiced extensively by industry
Ion exchange	removal of ions by sorption on surface of a solid matrix	synthetic cation anion exchange resins	may require pH adjustment	cyanide-99% chromium-98% copper-95% iron-100% cadmium-92% nickel-100% zinc-75% phosphate-90% sulfate-97% aluminum-98%	1-operates at ambient environment 2-well suited to automatic control 3-can be used to recover valuable constituents	1-produces wastewater effluent 2-resin is subjected to attack by oxidizing agents (i.e. nitric acid) 3-subjected to clogging and fouling 4-costly to operate	periodic regeneration of resins	used primarily in water treatment operation for production of boiler feed-water
Liquid/liquid extraction	removal of soluble organics or chemically charged pollutants	immiscible solvents that may contain chelating agents	may require pH adjustment	phenol-99% chromium-99% nickel-99% zinc-99% fluoride-68% iron-99% molybdenum-90%	1-can be used to recover valuable constituents	1-effluent required additional treatment 2-subjected to chemical interference 3-solvent system may deteriorate with repeate use	periodic regeneration of solvent	process is not highly developed for industrial use (except phenol extraction)

Table VII-1. END-OF-PIPE TREATMENT METHODS (CONTINUED)

Method	objectives	Chemicals or equipment used	Process requirements	Efficiency of removal	Advantages	Limitations	Required maintenance	Demonstration status
Disinfection	destruction of microorganisms	chlorine, hypochlorite salts, phenol,phenol derivatives, ozone, salts of heavy metals, chlorine dioxide	may require pH adjustment		1-operates at ambient environment 2-well suited to automatic control	1-may cause taste and color problems 2-disinfectant are toxic compounds	periodic loading of chemicals	disinfection by chlorine is practiced extensively by industry
Adsorption	removal of sorbable contaminants	activated carbon, synthetic sorbents	may require pH adjustment	depend on the nature of pollutants and composition of waste	1-high removal efficiency for trace concentration 2-low energy requirement 3-operates at ambient environment	1-waste required pretreatment 2-bed required regeneration 3-losses of sorbent during regeneration	periodic regeneration of sorbent	practiced extensively by industry
Chemical oxidation	destruction of cyanides	chlorine, hypochlorite salts, ozone	pH=9 5-10 (first step) pH=8 (second step)	99.6%	1-operate at ambient temperature 2-well suited to automatic control	1-require careful pH control 2-may produce poisonous gas 3-second reaction is slow 4-subjected to chemical interference	periodic removal of sludge and loading of chemicals	practiced extensively by industry
Distillation	separation of dissolved matter by evaporation of the water	1-multistage flash distillation 2-multiple-effect long-tube vertical evaporation 3-submerged tube evaporation 4-vapor compression	may require pH adjustment	100%	1-produces high quality water 2-can be used to recover valuable constituents	1-high energy requirement 2-may require pretreatment of waste 3-cause scaling of boilers and heat exchangers 4-may require post treatment of water	periodic cleaning to remove scale	practiced only to a moderate extent by industry, primaril the submerged tube type unit
Reverse osmosis	separation of dissolved matter by filtration through a semipermeable membrane	1-tubular membrane 2-hollow-filter modules 3-Spiral-wound flat sheet membrane		TDS-93%	1-produces high quality water 2-can be used to recover valuable constituents 3-operates at ambient temperature	1-limited range of operating temperatures and concentrations 2-membrane is susceptible to fouling by suspended solids or attack by many chemicals	periodic replacement of membrane	very limited use in industrial wastewater treatment
Electrodialysis	removal of dissolved polar compounds	solute is exchanged between two liquids through a selective semipermeable membrane in response to differences in chemical potential between two liquids		TDS-62-96%	1-can be used to recover and reuse valuable chemicals 2-produces high quality water	1-membrane is subjected to fouling by suspended solids 2-membrane and electrode are subjected to corrosion by	periodic replacement of membranes and electrodes	not practiced by industry

Table VII-1. END-OF-PIPE TREATMENT METHODS (CONTINUED)

Method	objectives	Chemicals or equipment used	Process requirements	Efficiency of removal	Advantages	Limitations	Required maintenance	Demonstration status
Freezing	separation of solute from liquid by crystallizing the solvent	1-direct refrigeration 2-indirect refrigeration		>99.5	1-produces high quality water 2-low operating temperature inhibits corrosion	1-high energy requirement 2-refrigerant may be contaminated in the direct refrigeration method	periodic cleaning and replacement of filters and screens	unproven method in waste treatment application

Table VII-2. SOLID/LIQUID SEPARATION SYSTEMS

Unit operation	Process objectives	Methods or units used	Retention time	Chemicals used	Efficiency of removal	Advantages
Skimming	removal of floating solids or liquid wastes from the water		1-15 min	none	70-90%	1-simple to operate 2-reduces down stream treatment 3-high efficiency of removal
Clarification	removal of suspended solids by settling	1-settling ponds 2-clarifiers	45 min	coagulants, coagulant aids, pH adjustment	to 15 mg/l	1-high efficiency of removal in short time and space
Flotation	separation of suspended solids by flotation followed by skimming	1-froth flotation 2-dispersed air flotation 3-dissolved air flotation 4-gravity flotation 5-vacuum flotation	20-30 min	aluminum and ferric salts, activated silica organic polymers	90-99%	1-efficient process
Microstraining	removal of suspended solids by passing the wastewater through a microscreen		N/A	none	70-80% (23µ) 50-60% (3µ)	1-no chemicals requirement 2-low cost of operation and maintenance 3-high efficiency of removal of large particles
Filtration	removal of suspended solids by filtration through a bed of sand and gravel	1-multimedia bed 2-mixed media bed	N/A	none	50-99%	1-low initial and operating costs 2-small land requirement 3-no chemicals requirement 4-partial removal of dissolved matter
Screening	removal of large solid matter by passing through screens	1-coarse screens 2-bar screens 3-communicating devices	N/A	none	50-99%	1-protect down stream treatment equipment 2-inexpensive devices
Thickening	concentration of sludge by removing water	1-gravity thickening 2-air flotation thickening	N/A	none	depends on the nature of sludge	1-facilitates further sludge processing at minimum cost 2-flotation thickeners are more efficient than gravity thickeners
Pressure filtration	separation of solid from liquid by passing through a semipermeable membrane under pressure		1-3 hrs	none	to 50-75% moisture content	1-high separation efficiency for difficult to remove solids 2-filter cake has a low water content 3-suspended solids content of filtrate is low 4-minimum maintenance
Heat drying	reduce the water content of sludge	1-flash drying 2-spray drying 3-rotary kiln drying 4-multiple hearth drying	N/A	none	to 8% moisture content	1-produces disposable product
Ultrafiltration	separation of macromolecules of suspended matter from the waste by filtration through a semipermeable membrane under pressure		N/A	none	Total solid removal of 95% and above	1-low capital installation and operating costs 2-unsensitivity to the chemical nature of waste 3-no waste pretreatment is required
Sandbed drying	removal of moisture from sludge by evaporation and drainage through sand.	1-covered beds 2-uncovered beds	filtration 1-2 day	none	as filter 15-20%	1-low costs of construction, operation and maintenance
Vacuum filtration	solid liquid separation by vacuum			none	produces 30% solid in filter cake	1-highly efficient process
Centrifugation	liquid/solid separation by centrifugal force	1-disc centrifuge 2-basket centrifuge 3-conveyor type centrifuge	N/A	none	moisture is reduced to 65-70%	1-small space requirement 2-simplicity in operation
Emulsion breaking	separation between emulsified oil and water		2-8 hour	aluminum salts, iron salts, pH adjustment (3-4)	>99%	1-highly efficient process

Table VII-2. SOLID/LIQUID SEPARATION SYSTEMS (CONTINUED)

Unit operation	Limitation	Energy requirement	Maintenance	Demonstration status
Skimming	1-limited to wastewater containing floating matter	small	periodic lubrication	practiced extensively by industry
Clarification	1-high operating cost	nominal	periodic loading of chemicals and removal of sludge	practiced extensively by industry
Flotation	1-efficiency depends on the nature of the particles surface	nominal	routine maintenance of pumps and motors	practiced extensively by industry
Microstraining	1-may result in high head loss 2-low efficiency of removal of small particles	small	routing cleaning of screens	practiced only to a moderate extent, primarily in municipal wastewater treatment plants
Filtration	1-wastewater with high suspended solids content require pretreatment 2-high losses of head 3-produces wastewater 4-operation is comlicated and requires training	small	routine maintenance of pumps	practiced extensively primarily in water treatment plant
Screening	1-minor effect on overall treatment 2-may result in high head loss	small	periodic cleaning	practiced extensively by industry
Thickening	1-sensitive to flow rate of both effluent and sludge removal	small	periodic cleaning lubrication	practiced extensively by industry
Pressure filtration	1-short life of filter cloth 2-requires operating personnel	small	periodic cleaning and replacement of filter	not practiced by industry
Heat drying	1-costly process	high	periodic cleaning	rotary kilns are used by industry to small extent
Ultrafiltration	1-limited range of operating temperature 2-membrane is susceptible to attack by many chemicals 3-limited range of applications 4-membrane can be fouled by suspended solids	nominal	routine maintenance of pumps	used by industry primarily to treat oily waste
Sandbed drying	1-requires a large area of land	small	periodic removal of sludge	practiced extensively by industry
Vacuum filtration	1-high operating cost 2-filtrate may require further treatment	nominal	periodic cleaning and replacement of filter media	practiced extensively by industry
Centrifugation	1-high operating cost 2-may produce noise	nominal	periodic lubrication and cleaning	equipment for industrial wastewater treatment is under development
Emulsion breaking	1-requires segregation of oily waste from non oily waste	small	routine maintenance of pumps and motors and periodic removal of sludge	practiced extensively by industry

Table VII-3. TREATMENT OF MAJOR POLLUTANTS

Pollutant	Treatment method	Residual concentration achievable (mg/l) (17)
Common		
pH	1 - Neutralization	to pH of 5.5 to 9
Total suspended solids	1 - Clarification	5-30
	2 - Flotation	5-15
	3 - Filtration	2-10
Specific		
Oil and Grease	1 - Skimming	10-30
	2 - Gravity flotation	20
	3 - Dissolved air flotation	15
Hexavalent chromium	1 - Chemical reduction	0-1
Chromium (total)	1 - Precipitation	0.006
	2 - Ion exchange	0.01
Iron	1 - Precipitation	0.3
Copper	1 - Precipitation	< 1.
	2 - Ion exchange	0.03
Zinc	1 - Precipitation	0.5-2.5
	2 - Ion exchange	20
Chlorine	1 - Dissipation	Below detection limits
	2 - Aeration	Below detection limits
	3 - Chemical reduction	Below detection limits

grease levels as low as 10-20 mg/l, while multistage units can achieve 2-10 mg/l.

Chromium. The most common method of chromium removal is chemical reduction of hexavalent chromium to the trivalent ion and subsequent chemical precipitation. The standard reduction technique is to lower the waste stream pH to 3 or below by addition of sulfuric acid, and to add sulfur dioxide, sodium bisulfite (or metabisulfite or hydrosulfite), or ferrous sulfate as a reducing agent. Trivalent chromium is then removed by precipitation with lime at pH 8.5-9.5.

The residual of hexavalent chromium after the reduction step depends on the pH, retention time, and the concentration and type of reducing agent.

A process for chromate removal from cooling water has been recently developed. This is an electrochemical process whereby an electrical current is applied to a consumable iron electrode. The resulting ferrous ions react with the wastewater chromate in accordance with the following equation:

$$3\ Fe^{2+} + CrO_4^{=} + 4\ H_2O = 3\ Fe^{3+} + Cr^{3+} + 8OH^{-} \qquad (1)$$

Because of the alkaline pH both the iron and chromium precipitate as metal hydroxides and are subsequently removed in a clarifier. The produced ferric ion further enhances the coagulation and settling of suspended solids.

Chromate residuals from this process have been reported to be less than 0.05 ppm. Costs of treatment are claimed to be fairly low and the operation is automaticall controlled. The process is also applicable for removal of other metals ions such as zinc, copper, nickel, tin, iron, etc. (16).

Copper. Effluent concentrations of less than 1 mg/l can be consistently achieved by precipitation with lime employing proper pH control and proper settler design and operation. The minimum solubility of the metal hydroxide is in the range of pH 8.5-9.5. In a power plant, copper can appear in the wastewater effluent as a result of corrosion of copper-containing components of the necessary plant hydraulic systems. Normally, every practicable effort is made, as a part of standard design and operating practice to reduce corrosion of plant components. Copper is not usually used in construction of once-through boilers and consequently, is rarely found in corresponding spent cleaning solutions (12).

Iron. In general, acidic and/or anaerobic conditions are necessary for appreciable concentrations of soluble iron to exist. "Complete" iron removal with lime addition, aeration, and settling followed by sand filtration has been reported. Existing technology is capable of soluble iron removals to levels well below 0.3 mg/l. Failure to achieve these levels would be the result of improper pH control. The minimum solubility of ferric hydroxide is between 7 and 8 (12). In some cases, apparently soluble iron may actually be present as finely divided solids due to inefficient settling of ferric hydroxide. Polishing treatment such as rapid sand filters will remove these solids. In a power plant, iron, as with copper, can appear in the wastewater effluent as a result of corrosion to iron-containing components of the necessary plant hydraulic systems. Normally, every practicable effort is made, as a part of standard design and operating procedure, to reduce corrosion of plant components. Excessively stringent effluent limitations on iron, as with copper, may necessitate complete design and alteration of condenser cooling and other systems.

Zinc. Lime addition for pH adjustment can result in precipitation of zinc hydroxide. Operational data indicate that levels below 1 mg/l zinc are readily obtainable with lime precipitation. The use of zinc can be minimized since other treatment chemicals are available to reduce corrosion in closed cooling water cycle. Zinc removals have been reported for a range of industrial systems and, generally, treatment is not for zinc alone.

END-OF-PIPE TECHNOLOGY FOR MAJOR WASTE STREAMS

The regulations describe the various wastewater streams as low volume waste sources, ash transport water, metal cleaning wastes, boiler blowdown, and cooling system wastes. It is also possible to classify wastewater streams by their temporal distribution into continuous, periodic, and occasional. Continuous wastewater streams will have to be treated on a continuous basi. The main tratment criteria is therefore the rate of flow. Periodic wastewater streams will generally be treated on a batch basis and discharged at a controlled rate. The treatment criteria are therefore the volume of each batch, the frequency of occurrence, and the rate of discharge from treatment.

Some waste streams, such as boiler blowdown, will not be discharged if the plant is not producing power. For some facilities, cooling water pumps continue operation even when power is not being generated. Others are related to the cumulative amount of energy produced by the plant, but may be discharged at the time the plant is not in operation. Metal cleaning wastes are an example of this type of waste.

Continuous Waste Streams. Continuous wastewater streams consist primarily of cooling system wastes, either of the once-through or the recirculating system blowdown type. None of the plants contacted in this study were found to discharge once-through cooling water to publicly-owned treatment facilities. Where such discharge occurs, consideration should be given to removing this discharge from the sanitary sewer system, since the large hydraulic loading will decrease the effectiveness of the POTW treatment process.

Residual chlorine contained in once-through cooling water discharges can be removed by so-called "dechlorination" processes. Methods of dechlorination include addition of reducing chemicals, passage through fixed beds of activated carbon and aeration. Reducing chemicals include sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$), and sodium sulfite (Na_2SO_3). Of these agents, sodium bisulfite is most commonly used (19). Granular activated carbon as adsorb chlorine compounds and is oxidized by it to carbon dioxide. Oxidizing chlorine compounds such as chlorine (Cl_2), hypochlorous acid (HOCl), chlorine dioxide (ClO_2) and nitrogen trichloride (NCl_3) are sufficiently volatile to be removed by aeration (19). Other active chlorine species are not as volatile and may not be removed. Data available to date do not indicate that heat discharged in this waste is a problem to a POTW.

Closed cycle or recirculating cooling water system blowdown is discharged into POTWs by a number of plants. The discharge may be continuous or intermittent. Significant parameters of pollutants that may be found in cooling water blowdown may include chlorine, hypochlorous acid, sodium hypochlorite, phosphates, chromates, zinc compounds, organic biocides, dispersing agents, and depending on the constituents in the makeup water supply, various inorganic salts resulting from the concentration of those constituents and the necessity of maintaining the pH within certain limits. Pretreatment may be necessary if certain types of inhibitors and biocides are used as internal treatment in the cooling water system. These are likely to inhibit biological activity at the publicly-owned treatment facilities and will therefore have an adverse effect on the treatment operation. The extent of this effect will depend on the relative volumes of cooling tower blowdown and domestic wastewater. Organic compounds used as inhibitors, biocides, or dispersing agents are not likely to be degraded by secondary biological treatment and will therefore pass through the publicly-owned treatment facilities and be discharged to the receiving waters. Toxicity studies are being conducted with individual proprietary compounds in order to establish permissible levels of discharge.

End-of-pipe technology is available to remove most inorganic pollutants. Many inorganic pollutants have low solubilites at alkaline pH, and can be removed by adding lime or another form of alkali. The degree of removal is a function of the solubility of the pollutant at high pH. Some specific pollutants such as chromium can be removed by ion exchange, but the ultimate disposal of the spent regenerants presents problems.

Periodic Wastes. Periodic wastes include waste resulting from boiler and service water treatment, boiler blowdown (can be continuous), ion exchange water treatment, water treatment evaporative blowdown, boiler and air heater cleaning, other equipment cleaning, laboratory and sampling streams, floor drainage, cooling tower basin cleaning, blowdown from recirculating wet-scrubber air pollution control systems, and other relatively low volume streams. These include all the wastes that are classified as "ash transport" and "metal cleaning" wastes. For plants discharging wastes to publicly-owned treatment facilities, boiler blowdown is generally not a significant source of pollution. Water treatment wastes may or may not be significant depending on the source of the water and method of treatment. Since most plants discharging wastes to publicly-owned treatment facilities also obtain their water from the municipal water supply system, the wastes will consist of normal constituents of the water supply, plus any chemicals used in the treatment process. If the treatment process is ion exchange, the wastes will contain inorganic acids and alkalis. Combination of wastes from anion and cation exchanges will generally result in combined waste stream that is acceptable to the treatment plant. If the pH of the combined waste stream is outside the range of 6.0 to 9.0 normally acceptable to biologically based treatment process, neutralization may be required.

Evaporation blowdown is usually high in dissolved solids, but otherwise acceptable for discharge to the publicly-owned treatment facilities. The dissolved solids consist primarily of concentrated constituents of the public water supply and do not have any adverse effect on the treatment plant. receiving water.

Floor drains may be a significant source of pollution, with oil and grease as the most significant parameter. The regulations for direct discharge limit oil and grease for all low volume wastes taken collectively to 20 mg/l on any one day, and 15 mg/l average for 30 consecutive days, but local authorities may impose more severe limits. Most municipal pretreatment ordinances also limit oil and grease so that pretreatment may be required for removal of this pollutant.

End-of-pipe technology is available and is used by some plants. The technology consists of gravity separators, either unassisted or assisted by flocculants and/or dissolved air flotation, followed if necessary by filtration. The technology is able to meet the desired standards at a minimal cost. However, to meet desired standards efficiently only those waste streams containing excessive oil and grease should be passed through the treatment unit.

Metal Cleaning Wastes. The most significant of the periodic wastes in terms of their potential impact on the publicly-owned treatment facilities are metal cleaning wastes. Metal cleaning wastes are produced intermittently while units are shut down. The efficiency of electric power production depends largely on the efficiency of heat transfer between the combustion products and the boiler water. All metallic heat transfer surfaces have a tendency to either corrode or collect deposits. Both corrosion products and deposits reduce the efficiency of heat transfer and must therefore be removed periodically.

There are two main types of cleaning operations: waterside and fireside. Waterside cleaning consists of cleaning the inside of tubes, and other boiler water passages. Due to the inaccessibility of these surfaces, the only practical and generally accepted method of cleaning is by chemical means. The cleaning typically proceeds in three stages: a bromate soak, an acid cleaning (usually inhibited hydrochloric acid), and finally a passivation stage. The total operation takes about two days and produces about five boiler volumes of wastes, with each stage consisting of a fill, drain, fill and rinse operation lasting about one and one-half to two hours. For multi-unit plants, only one boiler is cleaned at any one time, so that the majority of the plant is operating during the cleaning cycle.

Fireside cleaning is more mechanical, consisting of high pressure nozzles directed against the surfaces to be cleaned. The cleaning solution often contains alkalis to dissolve oil, and grease and detergents to keep the removed material in colloidal suspension. Fireside cleaning is done on both the fireside of the boiler. SImilar cleaning procedures are employed on the air preheater.

Pollutants contained in the cleaning solutions consist of both the chemicals used in the cleaning solution and the material removed from the heat transfer surfaces. Tables VII-4 and VII-5 give ranges of composition for chemical cleaning and fireside cleaning wastes, respectively. These pollutants are generally not removed by biological secondary treatment and may have an adverse effect on the treatment process, depending on the ratio of metal cleaning wastes to total flow at the publicly-owned treatment plant.

Options for process modifications for metal cleaning wastes are small. End-of-pipe technology is available for the removal of most of the pollutants resulting from metal cleaning operations.

Basic technology for removing pollutants from the waste stream consists of retention, storage and combination of waste streams, raising the pH to precipitate metallic salts, removal of precipitated solids and pH readjustment of final effluent for discharge to public sewers. Operating data from many power plants shows that copper from the metal cleaning wastes can be reduced to less than 1 mg/l by lime or caustic soda addition. Two of these plants use chelating agents in their cleaning process while all of the remaining facilities do not. The power plants which discharge into POTW can achieve the 1 mg/l copper limitation more readily since they do not have to reduce iron at the same time to 1 mg/l.

Since metal cleanings are infrequent operations, (some plants clean their boiler only once every five years) 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 who are generally being asked to include waste treatment and disposal as part of the cleaning contract.

Ash Transport Water. Hydraulic systems for handling bottom ash are used primarily by coal-fired plants. The preliminary listing of plants discharging to publicly-owned treatment plants contain coal-fired plants. Hydraulic systems are used for fly ash removal, usually in conjunction with scrubbers for sulfur dioxide removal. Where scrubbers are part of the air pollution control system, provision has to be made for handling of the sludges resulting from the operation. This sludge is not suitable for disposal to the public sewer system.

Air Pollution Control Wastes. There is normally little liquid effluent from sulfur dioxide scrubbers. The water within the system is usually recycled as much as possible by dewatering the sludge to a filter cake. Some water leaves the system as steam with the gaseous emissions and some water becomes entrained in the sludge cake, but the objective of good operation is to minimize the amount of water in the sludge cake. The water retained in the sludge cake is sufficient to meet the requirements for system blowdown.

Table VII-4. TYPICAL COMPOSITION OF BOILER CHEMICAL CLEANING WASTES

Component	Amount, lb.
Hydrochloric Acid	46,500
Iron	3,800
Copper	500
Sodium Bromate	930
Ammonium Carbonate	1,675
Ammonium Hydroxide	14,600
Chromate Inhibitors	1,600
Thiourea	7,750
Ammonium Bifluoride	3,775
Sodium Carbonate	7,750

plus small amounts of silica, phosphates, nickel, zinc, aluminum, titanium, manganese and magnesium.

Size of unit	500 MW
Volume of wastes	95,000 gal

Table VII-5. TYPICAL COMPOSITION OF BOILER FIRESIDE WASH WASTES

Component	Concentration, mg/l
Suspended Solids	1,000 - 3,000
Iron	500 - 1,000
Copper	10 - 20
Nickel	50 - 300
Zinc	15 - 25
Oil and Grease	150 - 300
Volume, gal/KW IGC (once/year for each boiler)	200 - 1,000

Occassional Wastes. Occassional wastes are those that are caused by contamination of stormwater runoff by materials stored on the plant site. The principal type of contaminated stormwater is coal pile runoff, and this is restricted to coal fired plants. A significant number of urban plants have been converted from coal to oil fired, but still retain the coal capability and may keep a coal reserve stored on the site. The coal reserve may become a significant source of pollution due to the interaction of water and air with some of the impurities in the coal, notably iron and sulfur. No plants discharging coal pile runoff to publicly-owned treatment facilities were uncovered during the industry survey.

A type of process modification would be to cover the inactive coal pile with plastic sheeting the way a baseball infield is covered in the rain. This would eliminate the formation of pollutant containing waste stream. Alternately, the waste stream, once produced, can be neutralized with lime as an end-of-pipe treatment, and any suspended solids allowed to settle. This practice is common in related industries.

WATER MANAGEMENT

The varied uses that are made of water in a power plant and the wide range of water quality required for those uses present this industry with an unusual opportunity for water management and wastewater reuse. Indeed, many plants developed water management programs that make use of all the wastewater streams produced by recycling them into unit processes which tolerate lower water quality (e.g. ash handling). However, to develop and implement a water management program of no discharge, it is necessary to evaluate the water requirement of each segment of the process as well as the specific factors which affect individual plant water needs. Such factors include the nature of the raw water source, the location of the plant and its climatic environment, water availability and water cost, and the local requirement for effluent limitations. The chemical composition of the raw water source affects the magnitude of the discharge from almost every segment of the process. To deionize water with high dissolved solids content to produce boiler feedwater, the ion exchange system produces more regenerant. Further, highly dissolved solids contents would also lower the concentration cycle of closed-loop recirculations cooling system, and therefore would increase the blowdown from these systems. In areas of excessive rainfall closed-loop recirculating systems would have to be bled more often to prevent the systems from overflowing and may indeed be difficult to operate. In areas where the rate of evaporation is greater than the rate of precipitation, such systems would require makeup water to maintain the flow. Water availability and cost would have an impact on the plant incentive to conserve water. The extent of wastewater treatment provided by the plant would depend on how stringent the local requirement for effluent limitations are.

IN-PLANT CONTROL TECHNIQUES

Control of wastewater effluents produced by the industry can be best achieved by incorporating in-process changes capable of reducing the volume of wastewater discharged, or reducing the amount of pollutants in the discharge.

Such changes can be classified under one of the following categories:

- Process modifications;
- Materials substitution;
- Water conservation and wastewater reuse;
- Raw materials and product recovery; and
- Good housekeeping practices.

Application of such techniques can result in multiple benefits, including savings in construction and operation costs of on-site wastewater treatment plants and in sewer surcharge and other charges associated with the use of publicly-owned treatment facilities.

In power generating plants there are theoretical opportunities for a number of such control measures. Practically, the opportunities are limited by the cost of any major process change under "retrofit" conditions, that is, conditions which require substantial mechanical and structural changes to an existing plant.

Process Modifications

A great number of process modifications are available to reduce the quantities of wastewater from a power generating plant, or to eliminate it altogether. In order to present these potential modifications in an orderly manner, this section has been further divided into subsections, each dealing with an individual wastewater stream.

Once Through Cooling Water. Switching from a once-through to a closed or open recirculating cooling system would greatly reduce the amount of wastewater discharged. This can be shown by balancing the quantity of heat rejected by each of the systems. For a once-through cooling system this quantity is equal to the product of the water flow times the condenser temperature rise. For a recirculating system it can be assumed that all the heat is rejected by evaporation. Neglecting drift and windage losses the following equation can be written:

$$\frac{B}{F} = \frac{T}{q(C-1)} \qquad (2)$$

where B/F is the ratio of the blowdown from a recirculating system to the discharge from once-through cooling system, T is the condenser temperature rise, q is the amount of heat required to evaporate a unit weight of water, and C is the concentration cycle. The concentration cycle is defined as the ratio of the concentration of a limiting parameter in the makeup water to that in blowdown. For a typical condenser temperature rise of 10°C and for q equal to 555 kcal/liter of water, even at a concentration cycle of 2, approximately 98 percent reduction in the volume of wastewater produced would be achieved. This reduction in cooling water consumption can also be classified under water conservation and wastewater reuse category.

Switching from once-through to a recirculating cooling syste, however, is costly and not always feasible. Power plants contacted in this study that utilize once-through systems discharge the effluent directly to surface water. Such discharges are subjected to EPA regulations which limit the temperature and the chlorine concentration of waste effluents to be discharged to surface water.

Excess total residual chlorine concentration in effluents from once-through cooling system can be minimized by monitoring and controlling free available chlorine concentrations in the discharge stream. A further technique to reduce total residual chlorine discharged is to chlorinate during periods of low condenser flow. Alternatively, the chlorine input to once-through cooling water can be reduced to a level below the concentration required for complete fouling control. Any biological growth which may result would be removed by mechanical means (12). This approach however, is limited by the configuration of the process piping and structures involved at any plant.

<u>Closed Condenser Cooling System Blowdowns</u>. Although the volume of recirculating cooling system blowdown is considerably smaller than the amount of wastewater discharged from a once-through system, it is also significantly more polluted. The effluent contains a higher dissolved solids concentration due to the evaporation of a large portion of the cooling water. In addition, chemicals added to inhibit scale formation, corrosion, and fouling would also be present in the blowdown water.

Blowdown from a recirculating cooling system can be disposed of by evaporation. In warm, dry climates, and where land costs are relatively low, such as in the southwest, blowdown streams can be collected in ponds and allowed to evaporate. Such ponds are usually lined with impervious material such as clay or plastic to prevent water infiltration and subsequent pollution of the groundwater aquifer (12).

The residual chlorine concentration in blowdown streams discharged to POTW can be controlled. This can be achieved by one of the following methods:

- Regulation through feedback instrumentation;
- Splitting the condenser influent into two streams and chlorinating one at a time;
- Reducing the length of the chlorination period.

Chlorination is now being questioned by health authorities who must meet increasingly stringent bacteriological and waste discharge requirements. An increased chlorine dosage which may provide satisfactory disinfection requirements may also be responsible for release of an excessive amount of polluting material to the aquatic environment. Current reports show that even trace amounts of chlorine are harmful to aquatic life (12).

Water Treatment Wastes. Substitution of reverse osmosis or electrodialysis for ion exchange to produce boiler feed water will greatly reduce the discharge from this section of the process. However, the technical feasibility of the reverse osmosis process is limited by the chemical characteristics of the raw water source and by economics, and for some plants polishing the product water by ion exchange will still be necessary, depending on the boiler operating pressure.

Ash Handling Wastes. Ash handling is the conveyance of the accumulated bottom and fly ash combustion solid waste product to a disposal system. This is accomplished by dry or wet processes. In the dry process the ash is transported to the disposal area by pressurized air, vacuum, or mechanical means. Dry ash handling systems do not generate wastewater and may allow a credit for the sale of the ash for its metal content. Bottom ash from oil fired furnace, for example, can be sold for its vanadium content.

The wet process can be either open or closed-loop systems. In the closed-loop system the ash is slurried in water and conveyed to a pond or clarifier where settling occurs. The clarified overflow from the settling pond is recycled to the boiler. The closed-loop ash handling system does not generate wastewater except in areas of excessive rainfall where the system must be periodically bled. In such cases the blowdown may be treated in a separate system to remove metal ion by precipitation and suspended solids by clarification. In areas where the rate of evaporation is higher than the rate of precipitation, evaporation losses from closed-loop ash handling systems can be supplemented with wastewater from other unit processes such as cooling tower blowdown. Open-loop ash handling systems are a source for wastewater since the transporting water is used but once to convey the ash to the settling ponds. This wastewater source can be eliminated by switching to dry or closed-loop type systems. Open-loop ash handling systems should be avoided when possible as the effluent from the ash pond may require additional treatment before it can be discharged.

Coal Pile Runoff. The extent of contamination of coal pile runoff can be reduced by properly constructing the coal storage area. Inactive coal piles can be sprayed with tar or covered with plastic sheeting to seal the surface to water infiltration. A drainage system should be constructed to collect the most polluted portion of the storm. In areas where the rate of evaporation is higher than the rate of precipitation runoff can be disposed of by evaporation in ponds. Alternatively, coal pile drainage can be used in processes which tolerate low quality waters such as ash handling systems. If the plant is located near a mine such water can be used in the coal washers to remove mineral matter. Diversion of this waste to ash ponds was also considered. However, because of the low pH of such wastes, coal ash can be leached by the water resulting in the formation of additional waterborne pollutants.

Air Pollution Control Scrubbing Devices. The non-recovery scrubbing process for SO_2 removal from flue gas may also be a source of wastewater if the system is bled to remove spent solvent. This is a closed-loop type system employing recycled lime scrubbing liquor. The process requires makeup water for saturating the boiler gases. Changing to SO_2 recovery systems would reduce the discharge from this part of the process as well as allow a credit for the sale of recovered sulfur dioxide or other sulfur products. Table VII-6 lists some of the SO_2 recovery processes currently available. It should be emphasized, however, that some of the listed processes have reached only the pilot plant stage of their development and cost estimates for their installation and operation are somewhat higher than those for the non-recovery processes.

Material Substitution

The blowdown from a recirculating cooling system can be reduced by increasing the concentration cycle. This can be achieved by substituting scale-forming ions with more soluble ions, or by using sequestering agents such as polyolesters and phosphonates to prevent deposition of precipitated solid phases. These dispersing agents, however, can become pollutants in the blowdown water.

Lime softening of cooling water makeup prior to its introduction into the system would also increase the concentration cycle, though it may be costly because of large volumes of water requiring treatment.

Installation of plastic or plastic-coated system components would reduce the extent of treatment of cooling water makeup. Plastic exhibits considerable resistance to corrosion and erosion. Many new installations using cooling towers employ plastic.

Where publicly-owned treatment plants containing a tertiary step are used, phosphate and nitrate based corrosion inhibitors could be substituted for chromates as these pollutants are removed by a tertiary treatment step. Chromate-based compounds can also be substituted by a recently developed synthetic organic corrosion formulation which is not as toxic as chromate to microorganisms. This formulation contains a blend of organic sequestrants and antifoulants for control of mineral and organic fouling together with corrosion inhibitors which provide protection to all system metals (14). Film-forming sulfophosphated organic corrosion inhibitor has also been developed. The substance is effective in both fresh and salty water, and may be considerably less toxic than chromate (14).

To reduce the amount of metals in wastewater from cooling system blowdown and from chemical cleaning operations, boilers and condenser cooling systems could be constructed of non-polluting materials. Tubes and piping could be made of special alloy metals or coated so as to reduce corrosion and scaling, but this can be prohibitively costly. Cooling towers can be constructed out of concrete and ceramic materials and thus reduce the need for additives to the cooling water system. Switching to low sulfur fuels can also eliminate the need for air pollution control devices.

Water Conservation and Wastewater Reuse

Different water uses in the plant require water of widely varying quality. These range from the almost zero solids requirements for boiler feedwater makeup to the almost unlimited solids allowed for ash transport water or scrubber water supply. Consequently, the wastewater produced in the

Table VII-6. RECOVERY PROCESSES FOR FLUE GAS DESULFURIZATION SYSTEMS

	Process	Sorbent System	Mode of SO_2 Removal	Sulfur Recovery	Product
1.	Double alkali system	Aqueous solution of Sodium hydroxide, Sodium sulfate, & sodium bisulfite	Chemical absorption oxides with $CA(OH)_2$	Precipitation of dissolved sulfur	Calcium sulfate Calcium sulfite
2.	Chemilbau system	Fluidized bed of activated carbon	Catalytic oxidation to H_2SO4 and physical absorption	Thermal stripping with hydrogen at 1000°F and catalytic reduction with H_2S	Sulfur, liquid $SO2$
3.	Hydrogen sulfite system	solution of sodium citrate, citric acid and sodium thiosulfate	Chemical absorption	Precipitation of dissolved sulfur with H_2S	Sulfur
4.	Wellman-Lord system	Aqueous solution of sodium sulfate and sodium bisulfite	Chemical absorption	Thermal regeneration by vacuum and catalytic reduction with natural gas	Sulfur
5.	Cat-O_x system		Catalytic oxidation of SO_2 to SO_3 with O_2 at 850°F (vanadium oxide)		78% sulfuric acid
6.	Shell flue gas system	A bed of cupric oxide supported by activated alumina	Oxidation to cupric sulfate		Concentrated SO_2

plant also vary widely in quality. This opens many opportunities for wastewater reuse.

Cooling system blowdown can be reused for ash transport or as scrubber water supply. Boiler blowdown water is usually better than the feed water supply and can be reused in the plant for other purposes.

Boiler blowdown can be reduced by installing a heat recovery system. In such a system the blowdown is discharged into a flash tank operating at a lower pressure than the boiler pressure. Because of the reduced pressure a portion of the blowdown water evaporates to form low pressure steam which can be condensed and reused as boiler feedwater. The reduction in blowdown that can be achieved by this method depends on the pressure difference between the boiler and the flush tank. The use of a heat recovery system for boiler blowdown will also increase the thermal efficiency of the plant.

Spent regenerants and rinses from the ion exchange system are also of a quality suitable for many purposes, where dissolved solids are not a limiting factor.

Some of the periodic waste streams could be recycled or reused if sufficient storage is available to hold these streams until needed. Metal cleaning wastes after pre-treatment or treatment could be used for low quality water uses such as ash transport or scrubber supply. However, the cost of storage may make such reuse prohibited.

Materials Recovery

Nearly all chromates, used as corrosion inhibitors, can be recovered using properly designed ion-exchange beds. Regenerant streams from the beds, which contain a relatively high concentration of chromate, can be returned to the cooling system as a usable corrosion inhibitor. Plants which soften boiler feedwater with lime can reuse lime sludge in their air pollution control system for SO_2 removal. Recoverying heat from boiler blowdown would reduce thermal discharges from this segment of the process, as well as increase the thermal efficienty of the process. Recycling of fly ash back to the furnace can be employed to increase thermal efficiency by burning products of incomplete combustion. It is also possible to recover vanadium from oil ash with high vanadium content. Spent regenerants from ion exchange system can be used where the quality of the acid and alkaline solutions is not critical. For example, the acid solutions can be used in recirculating cooling system to maintain the pH of the water below saturation.

Air pollution control devices, on the other hand, may require an alkaline source of water.

Good Housekeeping Practices

There are numerous alternative methods ranging from taking precautionary measures against spills of chemical solutions or oil to pump sealing to prevent leaks. Facilities should be constructed so that oil and grease contaminated water will not drain directly into other water systems or be diluted by rainfall runoff. Cleaning up oil spills, maintaining equipment to minimize leaks, and supporting an effective surveillance program will also minimize contamination of wastewater effluents. Controlling additions of chemicals to waters used in the various units of the process would reduce their concentrations in the effluents streams. Flow of water into the plant should be regulated in accordance with production rate.

SUMMARY

A variety of wastewater control and treatment technologies are available for the steam electric power industry. Since the water needs, and the requirements for wastewater discharge are specific to each individual plant, each control and treatment system must be developed in accordance with the individual plant requirement and should be integrated in a comprehensive water management program. Special consideration should be given to in-process control techniques. Often, such technique can be found easy and inexpensive to implement and yet, they can result in substantial reduction in water consumption and wastewater discharge.

SECTION VIII

COST, ENERGY, AND OTHER NONWATER QUALITY ASPECTS

INTRODUCTION

This section discusses cost estimates for control and treatment technologies described in previous sections, energy requirements for these technologies, and nonwater quality related aspects such as reuse of water within the plant. Ultimate disposal of brines and sludges, effect of land availability, user charges and pollutants limitations imposed by POTWs and other factors relating to the steam electric power generating point source category are also discussed in this Section.

Costs are developed in greater detail for those waste sources which potentially are discharged to POTWs and are potentially subject to pretreatment requirements. These include the following:

- o Low Volume Wastes
- o Metal Cleaning Wastes
- o Cooling Tower Blowdown
- o Area Runoff and Ash Pond Discharges

Other waste streams such as ash transport water, boiler blowdown, and once-through cooling water are provided in the latter part of this section.

The pollutants in discharges to POTWs are similar to those for direct discharge to surface water, as covered in the Development Document for this industrial category.

Discharges of wastewater needing pretreatment and the extent of pretreatment vary greatly from plant to plant depending on the fuel used, chemical additives employed, and a host of other variables. These variations influence the pretreatment costs so significantly that general industry costs presented in this section should be considered order of magnitude numbers.

For most power plant wastes, the pretreatment for discharge to POTW can involve control of three parameters of pollution, pH, suspended solids, and oil and grease. Control of pH neutralizes any undesirable acidity or alkalinity. Treatment for suspended solids then removes suspended metals as well as other suspended material. Oil and grease is separated from the water phase of the low volume wastes and skimmed off.

COST REFERENCES AND RATIONALE

Cost information contained in this report was obtained from the following sources:

- Engineering estimates based on published cost data for equipment, construction, and installation;
- Estimates and guidelines for estimating contained in the Development Document for steam electric industry discharges to surface water and the other EPA documents;
- Quotations for materials and supplies published in current trade journals.
- Cost data obtained as a result of direct inquiry to industry for data on actual installations.

Interest Rates and Equity Finance Charges

Capital investment cost estimates for this study have been based on 10 percent capital cost which represents a composite value for either interest rate paid or the required return on investment.

Time Basis for Cost Adjustment

All estimated costs are taken from July, 1976 prices or where necessary adjusted to this time basis using the ENR construction cost index of 2413 (July 1, 1976).

Useful Service Life

The useful service life of all wastewater treatment and disposal facilities is a function of the process involved, the quality of the equipment and design, its use patterns, the quality of maintenance and several other factors. Whereas individual companies often use service lives based on actual local experience, for the purpose of internal authorization, the Internal Revenue Service provides uidelines for tax computational purposes which are intended to reflect approximate average life experience.

The following useful service life values were chosen for use in this report from the literature, discussions with representatives of industry, and IRS guidelines data:

o	General process equipment	10 years
o	Buildings, sewers, ponds, etc.	20 years
o	Material handling equipment and vehicles	5 years

Depreciation

The allocation of the cost of capital assets such as treatment and disposal equipment less salvage (if any) over the estimated useful service life of the unit or facility in a systematic and rational manner as a non-cash expense is termed depreciation. For IRS tax purposes and to make suitable financial allowance for equipment replacement several types of depreciation are used. Simple straightline depreciation was used as the basis of calculations in this report.

Capital Costs

Capital costs have been defined for this study as all initial out-of-pocket cash expenditures for provision of wastewater treatment and disposal facilities. These costs will include research, development, and feasibility studies necessary to characterize and design the facilities land and site preparation costs when applicable, equipment, construction, installation, and start-up costs, costs of buildings, services and engineering (allocated where necessary), contractor profits and contingency costs if such exist.

Annual Capital Costs

Most capital costs are accrued during the year or two prior to actual use of the facility. This present worth sum can be converted to equivalent uniform annual disbursements over the life of the facility by utilizing the Capital Recovery Factor Method:

$$\text{Uniform Annual Disbursement} = \frac{(P)(i)(1+i)n}{(1+i)\underline{n}\quad 1}$$

where P = present value (capital expenditure),
i = interest rate, %/100
n = useful life in years

Operating Expenses

Annual costs of operating pretreatment facilities include labor, supervision, materials, maintenance, taxes, insurance, and power and energy. Operating costs combined with annualized capital costs give total costs for pretreatment operations.

Rationale for Model Plants

Plant costs are estimated for model plants rather than for any actual plant. Model plants are defined to have sizes of 25 MW and 500 MW capacity, which are representative of large and small-sized operation.

Definition of Levels of Treatment and Control

Costs are developed for various types and levels of technology:

Minimum (A or basic level). That level of technology which is equalled or exceeded by most or all of the involved plants.

Usually, money for this treatment level has already been spent (in the case of capital investment) or is being spent (in the case of operating and overall costs).

B,C,D--Levels. Successively greater degrees of treatment with respect to critical pollutant parameters. Two or more alternative treatments are developed when applicable.

Basis for Pretreatment Costs

In development of cost estimates found in Tables VIII-1, VIII-2, VIII-4, and VIII-5, it is assumed that only the following wastewater effluents are discharged to POTWs and may, therefore, require pretreatment.

- Low Volume Wastes
- Metal Cleaning Wastes
- Cooling Tower Blowdown
- Area Runoff and Ash Pond Discharges
- Boiler Blowdown

Low volume wastes include ion-exchange regenerants, spills, leaks, air pollution control system bleed offs, area washdowns, and other miscellaneous wastewater streams.

Metal cleaning wastes include tube and fireside boiler cleaning products, as well as air cleaner wastes.

Area runoff includes rainwater runoff from coal piles. Ash pond overflows and blowdowns are designated as discharges.

Costs have been addressed separately for the following wastes:

- Ash Transport Water
- Boiler Blowdown

Reasons for addressing these sources of wastes separately are discussed in detail in Section VII, but are also discussed briefly below.

Ash transport water from coal-fired plants is generally recirculated after sedimentation, and the purpose of sedimentation is process rather than pollution control. Overflows from ash ponds are included in the wastewater for pretreatment.

Boiler blowdown can be, and sometimes is, discharged to POTW without pretreatment. In can be handled at the combined plant without incremental costs. However, based on data contained in Section V the quality of boiler blowdown is better than that required for almost any in plant use, and it is recommended that boiler blowdown not be mixed with other waste streams for discharge to the POTW.

No plant contacted in this study was found to discharge once-through cooling water to a POTW. Therefore, costs are not generated for pretreatment requirements.

Cost Variances

The effects of age, location, and size on costs for treatment and control have been considered and are in the body of this section.

COSTS FOR PRETREATMENT

Waste types covered in this subsection include low volume wastes, metal cleaning wastes, cooling tower blowdown, area runoff and ash pond discharge. Since the wasteload differs depending on the fuel source used, cost estimates for pretreatment of wastewater effluents from steam electric plants have been divided into those plants burning gas or oil and those using coal.

Oil and Gas Fired Plants

Oil and gas-fired plants probably will have no ash pond discharge, no air pollution control wastewater, or coal pile runoff. Therefore, these plants have essentially ion-exchange regenerants, miscellaneous low volume wastes, cooling tower blowdown and metal cleaning wastes.

Estimated wastewater volumes in liters/day (GPD) for the plant sizes given are:

	25 MW Plant	500 MW Plant

o	Low Volume Wastes		
	Ion-exchange regenerants	11,400(3000)	454,000(120,000)
	Miscellaneous	3,800(1000)	151,400 40,000)
o	Metal Cleaning Wastes	380(100)	10,200(2,700)
o	Cooling Tower Blowdown	94,600(25,000)	1,892,000(500,000)

The low volume wastes contain primarily acids and/or bases and perhaps some oil. The metal cleaning wastes contain acids, bases, metals, oil and grease, and suspended solids. Cooling tower blowdown may contain chromates, chlorine, chlorinated phenols, mercury, phosphate, zinc and many other additives commonly used in cooling tower systems. For purposes of cost analysis, however, cooling tower blowdown is assumed to contain only free chlorine (chlorine is the most commonly reported biocide used).

Defined Pretreatment Levels

The raw wastes requiring pretreatment prior to POTW disposal are similar to those described in the Development Document for direct dischargers, and use has been made of the data on wastewater volumes, waste loads and other information contained therein. The minimum pretreatment level, defined as Level A, consists of that level of technology which is equalled or exceeded by most or all of the existing plants. This level involves some flow equalization and combining of wastes to get the benefit of some neutralizing and diluting effects. Expenditures, both capital and operating are small.

Level B pretreatment involves equalization of low volume wastes, neutralization to a pH 6-9 and skimming of surface oil. Metal cleaning wastes are stored in a large tank or small pond and fed slowly to the neutralization tank for small volume wastes and boiler blowdown. There is no pretreatment of cooling tower blowdown.

Level C pretreatment is the same as Level B except that the metal cleaning wastes are neutralized, clarified and discharged. Provision is made for sludge removal.

Level D pretreatment is essentially that for BPCTCA for direct discharge to surface water. For this level all waste streams with exception of the cooling tower blowdown are fed into a tank for pH adjustment (optimum in the 9-11 pH range), oil is skimmed from the liquid surface, and suspended solids are removed in a clarifier. Acid is then added to reduce pH to 6-9 prior to discharge. Cooling tower

TABLE VIII-1

WASTEWATER TREATMENT COSTS AND RESULTING WASTE-LOAD CHARACTERISTICS FOR TYPICAL PLANT

SUBCATEGORY Oil or Gas Fired Plant
PLANT SIZE 25 MW
PLANT AGE ----- YEARS PLANT LOCATION ----------

COSTS OF TREATMENT TO ATTAIN SPECIFIED LEVELS

COST CATEGORY	COSTS ($) TO ATTAIN LEVEL				
	A	B	C	D	E
TOTAL INVESTED CAPITAL	10,000	50,000	60,000	120,000	
ANNUAL CAPITAL RECOVERY	$1,600	8,150	9,760	19,500	
ANNUAL OPERATING AND MAINTENANCE COSTS (EXCLUDING ENERGY AND POWER)	Small	10,000	13,000	15,000	
ANNUAL ENERGY AND POWER COSTS	Small	Small	500	500	
TOTAL ANNUAL COSTS	1,600	18,150	23,260	35,000	

RESULTING WASTE-LOAD CHARACTERISTICS

PARAMETER	CONCENTRATION (mg/l) (ppm)					
	RAW (UN-TREATED)	AFTER TREATMENT TO LEVEL				
		A	B	C	D	E
(a) TSS	300	300	300	100	100	
Fe	1200	1200	1200	-----	<1.0	
Cu	200	200	200	< 1.0	<1.0	
pH	----	----	6-9	6-9	6-9	
Oil & Grease	----	----	-----	< 100	< 20	
(b) Free CL_2	----	----	-----	-----	0.5	

(a) Low volume and metal cleaning wastes combined
(b) Cooling Tower Blowdown
NOTE: TSS, Fe, and Cu, raw wastes concentrations estimated from Table A-V-20 of Development Document EPA 440/1-74029 a (12)
Level A - Flow Equalization
Level B - Equalization of low volume wastes, followed by neutralization to pH 6-9, skimming of surface oil. Metal cleaning wastes combined with low volume wastes and neutralized without sludge removal.
Level C - Same as Level B except metal cleaning wastes neutralized, clarified with sludge removal and discharged.
Level D - Equalization, pH adjustment, oil skimming, clarification, reacidification. Cooling tower blowdown treated with sulfite.

TABLE VIII-2

WASTEWATER TREATMENT COSTS AND RESULTING WASTE-LOAD CHARACTERISTICS FOR TYPICAL PLANT

SUBCATEGORY Oil or Gas Fired Plant

PLANT SIZE 500 MW

PLANT AGE ---- YEARS PLANT LOCATION ------------

COSTS OF TREATMENT TO ATTAIN SPECIFIED LEVELS

COST CATEGORY	COSTS ($) TO ATTAIN LEVEL				
	A	B	C	D	E
TOTAL INVESTED CAPITAL	80,000	300,000	300,000	700,000	
ANNUAL CAPITAL RECOVERY	13,000	48,800	48,800	114,000	
ANNUAL OPERATING AND MAINTENANCE COSTS (EXCLUDING ENERGY AND POWER)	Small	60,000	80,000	130,000	
ANNUAL ENERGY AND POWER COSTS	Small	1,000	2,000	3,000	
TOTAL ANNUAL COSTS	13,000	109,800	130,800	247,000	

RESULTING WASTE-LOAD CHARACTERISTICS

PARAMETER	CONCENTRATION (mg/l) (ppm)					
	RAW (UN-TREATED)	AFTER TREATMENT TO LEVEL				
		A	B	C	D	E
(a) TSS	300	300	300	100	100	
Fe	1200	1200	1200	-----	< 1.0	
Cu	200	200	200	<1.0	< 1.0	
pH	-----	------	6-9	6-9	6-9	
Oil & Grease	-----	------	-----	<100	< 20	
(b) Free CL_2	-----	------	-----	-----	0.5	

(a) Low volume and metal cleaning wastes combined

(b) Cooling Tower Blowdown

NOTE: TSS, Fe, and Cu, raw wastes concentrations estimated from Table A-V-20 of Development Document EPA 440/1-74029 a (12)

Level A - Flow Equalization

Level B - Equalization of low volume wastes, followed by neutralization to pH 6-9, skimming of surface oil. Metal cleaning wastes combined with low volume wastes and neutralized without sludge removal.

Level C - Same as Level B except metal cleaning wastes neutralized, clarified with sludge removal and discharged.

Level D - Equalization, pH adjustment, oil skimming, clarification, reacidification. Cooling tower blowdown treated with sulfite.

blowdown is treated separately with sulfite to remove free chlorine.

Costs and estimated effluent concentrations achieved for oil and gas-fired plants are given in Table VIII-1 and VIII-2.

Detailed model description for Level D is given in the following subsection.

Costs for Levels A, B, and C are roughly estimated from cost experience with similar wastewater volumes and compositions in other industries as well as from steam electric power plants.

Capital cost data for wastewater pretreatment facilities for oil and gas-fired steam electric power plants discharging to public sewerage systems are summarized in Table VIII-3.

Table VIII-3. SUMMARY OF CAPITAL COSTS OIL AND GAS-FIRED PLANTS 25 MW PLANT

$ Per KW IGC
Pretreatment Technology Level

Category	A	B	C	D
Low Volume Wastes	0.38	1.20	1.20	1.60
Metal Cleaning Wastes	0.02	0.80	1.20	1.0
Cooling Tower Blowdown	NT	NT	NT	1.66
Boiler Blowdown	NT	NT	NT	0.54
TOTAL COST	0.40	2.00	2.40	4.8

500 MW Plant

$ Per KW IGC
Pretreatment Technology Level

Category	A	B	C	D
Low Volume Wastes	0.15	0.50	0.50	0.79
Metal Cleaning Wastes	0.01	0.10	0.10	0.20
Cooling Tower Blowdown	NT	NT	NT	0.31
Boiler Blowdown	NT	NT	NT	0.10
TOTAL COST	0.16	0.6	0.6	1.40

Note: NA not applicable to discharge to POTW
NT Not treated

A - Flow equalization.

B - Equalization and neutralization of low volume wastes to pH 6-9, skimming of surface oil. Metal cleaning wastes and neutralized.

C - Same as Level B except metal cleaning wastes neutralized, clarified and discharged. Provision is made for sludge removal.

D - Equalization, pH adjustment, oil skimming, reacidification, clarification. Cooling tower blowdown treated with sulfite.

Coal-Fired Plants

Coal-fired plants have ash pond discharges, air pollution control wastewater, coal pile runoff, ion-exchange regenerants, miscellaneous low volume wastes, cooling tower blowdown and metal cleaning wastes.

Estimated wastewater volumes in liters/day (GPD) for the plants sizes given are:

	25 MW		500 MW	
o Low Volume Wastes				
- Air Pollution Wastes	3800	(1000)	151,400	(40,000)
- Ion Exchange Regenerants	11400	(3000)	454,000	(120,000)
- Miscellaneous	3800	(1000)	15,400	(40,000)
o Metal Cleaning Wastes	380	(100)	10,200	(2,000)
o Cooling Tower Blowdown	94,600	(25000)	1,892,000	(500,000)
o Area Runoff	3,800	(1000)	94,600	(25,000)
o Ash Pond Discharge	3,800	(1000)	75,700	(20,000)
o Boiler Blowdown				

The low volume wastes contain primarily acids bases and suspended solids. The metal cleaning wastes contain acids, bases, metals, and suspended solids. Cooling tower blowdown as discussed for oil and gas-fired plants may contain a variety of additives but for purposes of this cost development is assumed to contain only free chlorine. Area runoff contains acid, suspended solids and possibly some metals. Ash pond discharges contain suspended and dissolved solids.

The minimum level for pretreatments, defined as Level A, consists of that level of technology which is equalled or exceeded by most or all of the existing plants. This level involves some flow equalization and neutralization resulting from the combination of waste streams of differing pH. There is no control or treatment of runoff. Expenditures, both capital and operating are small.

Level B pretreatment involves equalization of low volume waste streams, neutralization to pH of 6-9. Metal cleaning wastes are stored in a large tank or small pond and fed slowly to the treatment system for low volume wastes. There is no control of area runoff.

Level C pretreatment is the same as Level B except that the metal cleaning wastes are neutralized, clarified and discharged. Provisions is made for the sludge removal. Level D pretreatment involves technology that will in general meet the requirements of BPCTCA for direct discharge to surface water. For this level area runoff from coal piles and ash transport water overflow are retained in a pond and fed continuously to a central pretreatment system. Metal cleaning wastes are similarly retained and fed continuously to the system. The pretreatment system itself is described in a following subsection. It consists primarily of a tank for pH control and oil skimming and a clarifier for suspended solids removal.

Costs and effluent quantities for the four treatment levels for coal-fired plants are summarized in Tables VIII-4 and VIII-5.

Capital cost data for wastewater pretreatment facilities for coal-fired steam electric power plants discharging to public sewerage systems are summarized in Table VIII-6.

Model Pretreatment Plants - Level C Technology

The interim final pretreatment standards required the reduction of copper in the metal cleaning wastes to 1 mg/l and of oil and grease to 100 mg/l in the plant's combined discharge to the POTW. The equipment required to achieve these standards are compatible to that required to achieve Level C. Although most, if not all, of the power plants can comply with the 100 mg/l of oil and grease requirement by employing good housekeeping techniques, cost data for oil skimmer are included.

Model pretreatment plant costs have been developed for power plants of 25 MW and 500 MW capacity of combined pretreatment facilities for low volume and metal cleaning wastes.

Estimates are for national average costs and do not consider regional differences in construction costs. All estimates are based on the following technology: pretreatment for pH adjustment to not less than 5, flow equalization so that the instantaneous peak discharge does not exceed five times the monthly average flow rate, removal of oil and grease from the plant's combined discharge to less than 100 mg/l, and reduction of copper to 1 mg/l from the metal cleaning wastes.

Estimated operating costs are presented for centralized pretreatment facilities for each model plant size. Operating costs include labor, fuel and power, chemicals, maintenance, residue removal and management. Actual operating costs may vary widely for those shown herein because of variations in processes, degree of automation, and allocation of joint labor costs.

Power plants sizes selected for model treatment plants are 25 MW and 500 MW. The 25 MW is typical of the smaller plants discharging to POTWs and listed in the ERCO survey sample (18). Eighty-seven and one half percent of all plants listed and discharging to POTWs have less than 100 MW IGC, with 37.5 percent having less than 25 IGC. Seventy-six percent of the generating capacity discharging to POTWs is in the size range between 250 and 1000 MW, and the 500 MW plant is considered representative of this large size group. For the 25 MW model plant it was assumed that pretreatment would be a batch operation with low volume and metal cleaning wastes combined. Treatment would consist of gravity separation (skimming) of oils, followed by lime precipitation of metals, sedimentation, withdrawal of sludge, adjustment of pH to a neutral range, and controlled discharge. Figure VIII-1 is a flow diagram for a small batch plant. For the 500 MW it was assumed that pretreatment would be on a semicontinuous basis. Metal cleaning wastes would be stored in an equalization tank and bled into the treatment operation at a controlled rate. The treatment process would consist of oil and grease skimming in the equalization tank, lime addition in the reactor, sedimentation and clarification, and final adjustment of pH before discharge to the public sewer. Sludge from the clarifier would be dewatered on vacuum filters, with the filtrate returned to the treatment plant influent. Figure VIII-2 is a flow diagram of this process.

Cost Variances

Age

Age affects the cost of pretreatment in terms of cost per unit of power produced primarily because age affects

TABLE VIII-4

WASTEWATER TREATMENT COSTS AND RESULTING WASTE-LOAD CHARACTERISTICS FOR TYPICAL PLANT

SUBCATEGORY Coal Fired Plant

PLANT SIZE 25 MW

PLANT AGE ---- YEARS PLANT LOCATION -----------

COSTS OF TREATMENT TO ATTAIN SPECIFIED LEVELS

COST CATEGORY	COSTS ($) TO ATTAIN LEVEL				
	A	B	C	D	E
TOTAL INVESTED CAPITAL	20,000	75,000	90,000	143,000	
ANNUAL CAPITAL RECOVERY	3,250	12,200	14,600	23,300	
ANNUAL OPERATING AND MAINTENANCE COSTS (EXCLUDING ENERGY AND POWER)	Small	15,000	18,000	20,000	
ANNUAL ENERGY AND POWER COSTS	Small	Small	500	500	
TOTAL ANNUAL COSTS	3,250	27,200	33,100	46,800	

RESULTING WASTE-LOAD CHARACTERISTICS

PARAMETER	CONCENTRATION (mg/l) (ppm)					
	RAW (UN-TREATED)	AFTER TREATMENT TO LEVEL				
		A	B	C	D	E
(a) TSS	300	300	300	100	100	
Fe	1200	1200	1200	-----	< 1.0	
Cu	200	200	200	<1.0	< 1.0	
pH	----	------	6-9	6-9	6-9	
Oil & Grease	-----	------	-----	<100	< 20	
(b) Free Cl_2	-----	------	------	-----	0.5	

(a) Low volume and metal cleaning wastes combined

(b) Cooling Tower Blowdown

NOTE: TSS, Fe, and Cu, raw wastes concentrations estimated from Table A-V-20 of Development Document EPA 440/1-74029 a (12)

Level A - Flow Equalization

Level B - Equalization of low volume wastes, followed by neutralization to pH 6-9, skimming of surface oil. Metal cleaning wastes combined with low volume wastes and neutralized without sludge removal.

Level C - Same as Level B except metal cleaning wastes neutralized, clarified with sludge removal and discharged.

Level D - Equalization, pH adjustment, oil skimming, clarification, reacidification. Cooling tower blowdown treated with sulfite.

TABLE VIII-5

WASTEWATER TREATMENT COSTS AND RESULTING WASTE-LOAD CHARACTERISTICS FOR TYPICAL PLANT

SUBCATEGORY Coal Fired Plant

PLANT SIZE 500 MW

PLANT AGE ----- **YEARS** **PLANT LOCATION** -----------

COSTS OF TREATMENT TO ATTAIN SPECIFIED LEVELS

COST CATEGORY	COSTS($) TO ATTAIN LEVEL				
	A	B	C	D	E
TOTAL INVESTED CAPITAL	100,000	350,000	350,000	790,000	
ANNUAL CAPITAL RECOVERY	16,300	57,000	57,000	128,500	
ANNUAL OPERATING AND MAINTENANCE COSTS (EXCLUDING ENERGY AND POWER)	Small	70,000	93,100	163,800	
ANNUAL ENERGY AND POWER COSTS	Small	2,000	2,500	3,000	
TOTAL ANNUAL COSTS	16,300	129,000	152,600	295,300	

RESULTING WASTE-LOAD CHARACTERISTICS

PARAMETER	CONCENTRATION (mg/l) (ppm)					
	RAW (UN-TREATED)	AFTER TREATMENT TO LEVEL				
		A	B	C	D	E
(a) TSS	300	300	300	100	100	
Fe	1200	1200	1200	-----	< 1.0	
Cu	200	200	200	< 1.0	< 1.0	
pH	-----	------	6-9	6-9	6-9	
Oil & Grease	-----	------	-----	< 100	< 20	
(b) Free CL_2	-----	------	-----	-------	0.5	

(a) Low volume and metal cleaning wastes combined
(b) Cooling Tower Blowdown

NOTE: TSS, Fe, and Cu, raw wastes concentrations estimated from Table A-V-20 of Development Document EPA 440/1-74029 a (12)

Level A - Flow Equalization

Level B - Equalization of low volume wastes, followed by neutralization to pH 6-9, skimming of surface oil. Metal cleaning wastes combined with low volume wastes and neutralized without sludge removal.

Level C - Same as Level B except metal cleaning wastes neutralized, clarified with sludge removal and discharged.

Level D - Equalization, pH adjustment, oil skimming, clarification, reacidification. Cooling tower blowdown treated with sulfite.

Table VIII-6. SUMMARY OF CAPITAL COSTS COAL FIRED PLANTS

25 MW Plant
$ Per KW IGC
Pretreatment Technology Level

Category	A	B	C	D
Low Volume Wastes	0.78	2.00	2.40	2.58
Metal Cleaning Wastes	0.02	1.00	1.20	1.2
Cooling Tower Blowdown	NT	NT	NT	1.66
Area Runoff	NT	NT	NT	0.19
Ash Handling Wastes	NT	NT	NT	0.19
Boiler Blowdown	NT	NT	NT	0.10
TOTAL COST	0.80	3.00	3.60	5.92

500 MW Plant

Category	A	B	C	D
Low Volume Wastes	0.19	0.60	0.60	0.92
Metal Cleaning Wastes	0.01	0.1	0.10	0.2
Cooling Tower Blowdown	NT	NT	NT	0.31
Area Runoffs	NT	NT	NT	0.05
Ash Pond Discharges	NT	NT	NT	0.05
Boiler Blowdown	NT	NT	NT	0.10
TOTAL COST	0.20	0.70	0.70	1.63

NOTE: NA - Not applicable to discharge to POTW
NT - Not treated

LEVELS OF PRETREATMENT

A - Flow Equalization
B - Equalization and neutralization of low volume wastes to pH 6-9 skimming of surface oil. Metal cleaning wastes combined with low volume wastes and neutralized without sludge removal.
C - Same as Level B except metal cleaning wastes neutralized, clarified and discharged. Provision is made for sludge removal.
D - Equalization, pH adjustment, oil skimming, clarification, reacidification. Cooling tower blowdown treated with sulfite.

efficiency and plants with lower effficiency will produce more wastes per unit of power produced. Plants with lower efficiency will also have lower utilization and therefore produce fewer units of power in relation to their installed capacity.

Size

Size is related to age in that the older plants are more likely to be smaller than the newer plants. This relation likely to be smaller than the newer plants. This relation is shown in detail in the Development Document (14). Size affects the cost of pretreatment as shown by the two plant sizes, 25 MW and 500 MW.

Location

Location affects costs of pretreatment because of differences in construction costs and labor rates in various parts of the U.S. and because the choice of the treatment technology and the cost of providing that technology are related to the availability of land. For plants discharging to public sewers, it may be assumed that they are located in urbanized areas, where land availability is somewhat limited. The extent of that limitation will vary widely depending on the size of the urban area, the location of the plant in that area, and the location of the area within the U.S. Cost estimates are presented for two cases, (1) where tankage can be constructed at ground level, and (2) where tankage must be supported on a steel framework over existing facilities because no other land is available.

COST ESTIMATES

Low Volume and Metal Cleaning Wastes

Low volume wastes include all wastewaters other than those for which specific effluent limitations have been established. Waste sources include wet air pollution control systems, water treatment systems, laboratory and sampling streams, floor drainage, cooling tower basin cleaning, and blowdown from service water systems. For the purpose of cost estimating, metal cleaning wastes have been combined with low volume wastes as the most cost effective method of handling these two waste sources. Pretreatment cost allottment to each type of waste has been estimated and the capital costs are given in Table VIII-9 and operating costs are given in Table VIII-8. This cost is conservative since most of the plants only need to treat for metal cleaning wastes.

Capital Costs

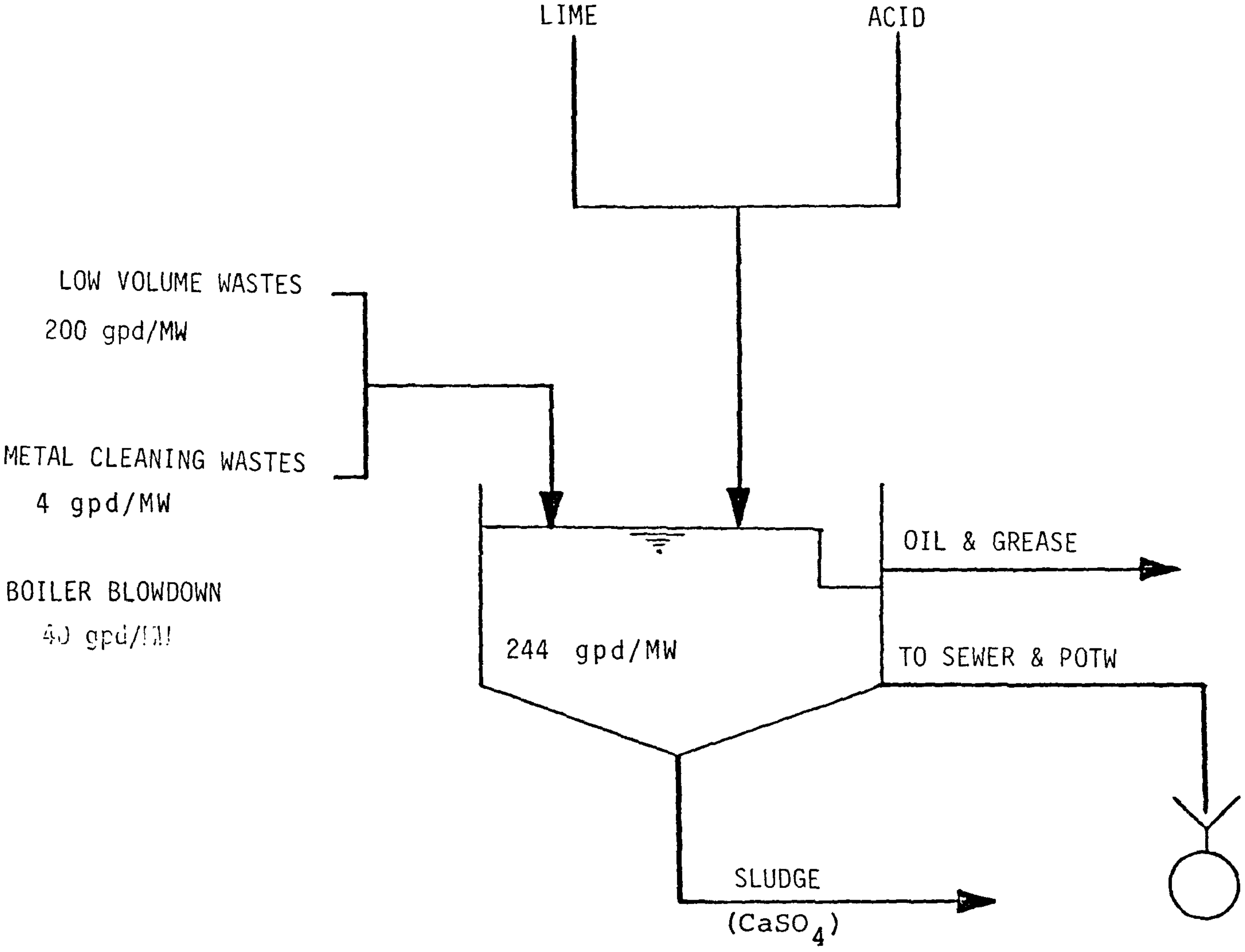


FIGURE VIII-1. Model Waste Pretreatment Plant 25 MW Generating Facility

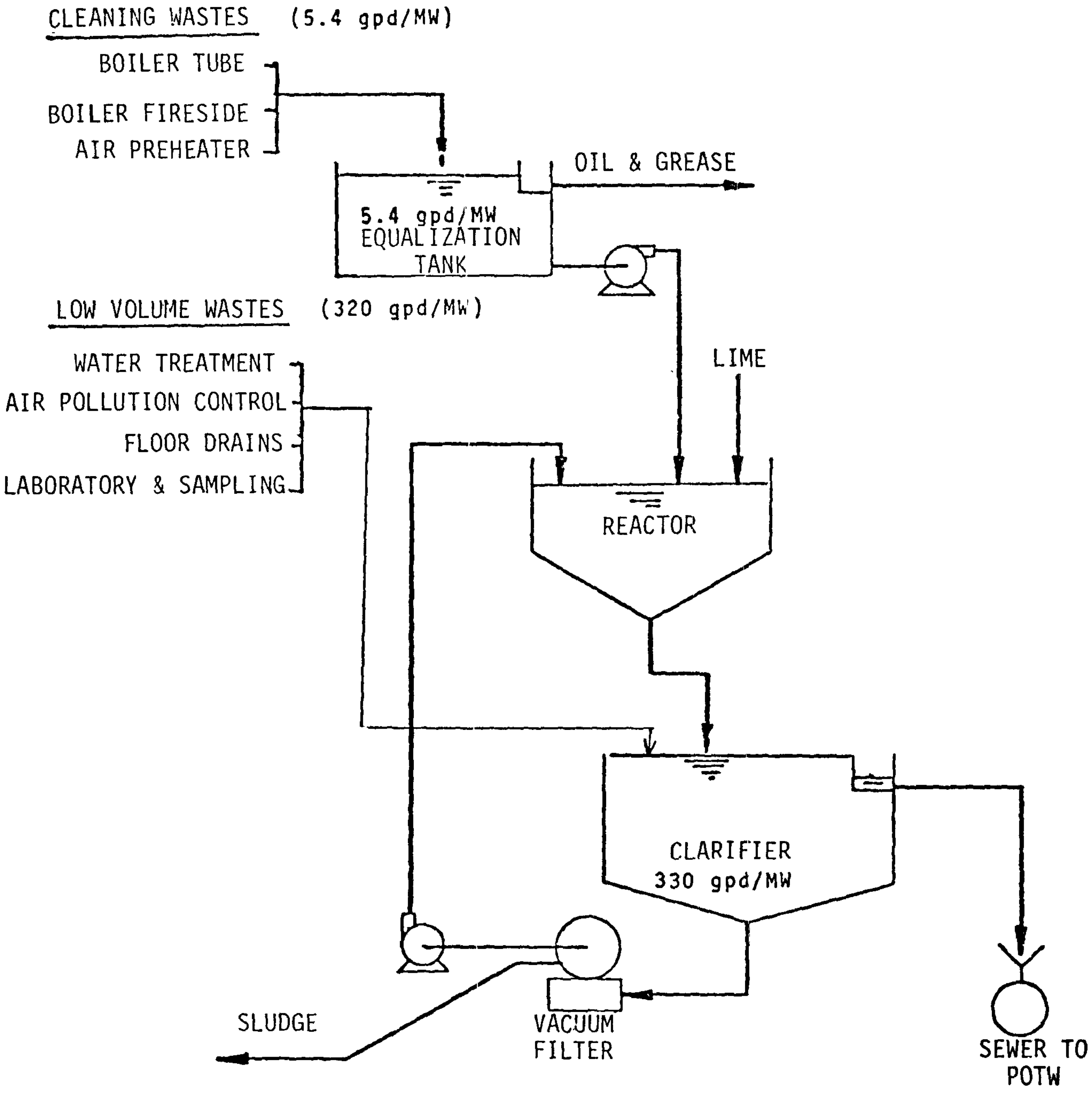


FIGURE VIII-2. Model Waste Pretreatment Plant 500 MW Generating Facility

Table VIII-9 provides estimated capital cost of pretreatment plants for control of low volume and metal cleaning wastes, where sufficient land is available to construct all facilities at ground level.

If land availability is limited, treatment plant components may have to be stacked vertically and tankage supported on steel framework. This would double the cost of the installation of the equipment.

Operating Costs

Operating costs include labor; fuel, power and other utilities; supplies (principally chemicals); maintenance; removal and disposal of residues; and management.

Assumed unit costs for basic parameters of operating costs are shown in the following table.

Table VIII-7. ASSUMED UNIT COSTS

labor, per hour, including fringe benefits	$8.50
Electricity, per kwh	0.04
No. 2 Fuel oil, per MM Btu	2.50
Chemicals	
Lime, per ton	30.00
Sulfuric Acid, per ton	50.00

Cost Data for Other Streams

Ash Transport Water

Ash transport water is the water used in the hydraulic transport of bottom or fly ash. Since the water serves only as a carrier of the ash, water quality is not a significant consideration. As a matter of fact, a high level of suspended solids is desirable since it facilitates the subsequent settling out and removal of the ash.

Settling basins are a normal component of ash transport systems. They may be either of the mechanical clarifier or natural lagoon (ash pond) type. Wet ash is removed from the clarifiers and disposed off site. The supernatent water is recycled to the process. The only routine blowdown from the system is the water removed with the wet ash. Waste streams result from overflows during periods of precipitation and for intermittant blowdown purposes.

At one of the plants visited, blowdown from a recirculating water system used to transport fly ash from oil fueled boilers was discharged to the POTW. This waste can be combined with area runoff and could be treated together.

Costs for pretreatment of discharges from ash transport systems are estimated from the volume of the portion coming to the retention pond.

Boiler Blowdown

The quality of boiler blowdown is generally higher than the quality of the raw water source, which for most plants discharging to POTWs is the municipal water supply. If boiler blowdown is discharged to the waste stream, it will tend to dilute the wastes and make any treatment less efficient. Boiler blowdown should therefore be returned to the plant service water system, and in most plants this is done. Therefore, no costs have been developed for pretreatment of this waste source.

Cooling System Wastes

Cooling system wastes are discharges of water that have been used to cool the main condenser surfaces. Cooling systems are either of the once-through or recirculating type. There are no known plants which discharge once-through cooling water to a POTW. Recirculating systems require blowdown which becomes a waste source.

Levels of Treatment

Levels A thru C treatment for cooling system blowdown consists of discharge to the POTW without pretreatment. If the only biocide or other cooling water treatment chemical used is chlorine and the POTW does not impose restrictions on chlorine in discharges to the sewer, cooling water blowdown may be discharged without pretreatment. In that case the only costs will consist of the sewer service charges. Level D treatment for residual chlorine consists of dechlorination and possible pH adjustment and meets the requirements of effluent limitation guidelines for BPT for direct discharge. Level D treatment for cooling water system blowdown is shown in Figure VIII-3.

Capital Costs

Table VIII-10 presents estimates for capital costs of pretreatment for cooling water system blowdown. These costs assume that chlorine is used as a biocide, that the POTW requires removal of residual chlorine, and that no other biocides or inhibitors unacceptable to the POTW are added to the cooling water system.

TABLE VIII-8
OPERATING COSTS-PRETREATMENT OF LOW VOLUME AND METAL CLEANING WASTES

Items		Installed Generating Capacity 25 MW(7)	 500 MW(8)
Operating Labor	(1)	$1,700	$17,000
Maintenance	(2)	3,000	18,000
Utilities			
Water	(3)	200	2,000
Electric Power	(4)	40	2,400
Sewer Charge	(5)	500	20,000
Chemicals and Supplies	(6)	15.000	101,000
Total		$20,440	$160,400
Annual production, KWH		2.0×10^8	4.0×10^9

Notes to Table VIII-8

(1) 25 MW Plant - 4 hrs/wk 200 hrs/yr
500 MW Plant - 40 hrs/wk 2000 hrs/yr

(2) 3% of capital cost

(3) City water @ .60/100 gall

(4) 25 MW Plant - 5 kwh x 200 hrs
500 MW Plant - 30 kwh x 2000 hrs

(5) Sewer service charge @ .30/1000 gal

(6) Lime 500 mg/l
Sulfuric Acid 100 mg/l

(7) Design flow: Low volume wastes: 5,000 gpd (from DD)
Metal cleaning wastes: 25,000 gallons batch

(8) Design flow: Low volume wastes 200,000 gpd (from DD)
Metal cleaning wastes: 500,000 gallons batch

Operating Costs

Operating costs for pretreatment of cooling system blowdown pretreatment consists of operating labor, maintenance, and chemicals for dechlorination. They are summarized in Table VIII-9.

Area Runoff

The area runoff subcategory includes runoff from material storage.

Coal is stored in open piles and oil is stored in covered tanks. Materials storage therefore represents a significant source of waste only for coal-fired plants. And since the burning of oil produces only about two percent of the amount of ash produced by the burning of coal, ash ponds are a feature of coal burning plants primarily. Material storage wastes from coal piles and ash ponds are therefore applicable to coal burning plants only.

No plants discharging area runoff to POTWs were found in the industry survey.

Level D treatment for coal pile runoff and ash pond overflows consists of neutralization and sedimentation. Its cost is a function of the size of the catchment area covered by the coal pile and the ash pond and the design meteorological conditions at the particular site. The regulation (40 CFR 423.40) require that treatment facilities be sized to treat the runoff from a 10-year, 24-hour rainfall event to produce an effluent having suspended solids of less than 50 mg/l and a pH between 6.0 and 9.0. The applicable technology consists of lined ponds capable of holding various volumes of runoff.

Capital Costs

For a 500 MW plant, a coal pile representing 90 days storage will occupy 10 - 40 acres. A retention basin designed to provide one hour detention at the maximum 10 minute rate associated with a 10-year, 24 hour storm will generally meet the effluent requirement. Depending on location, such a retention basin could cost $27,000, $96,000, exclusive of land, or $0.05-$0.19 per KW IGC.

Operating Costs

Operating costs for pretreatment facilities for runoff from coal piles and ash ponds are limited to chemicals for neutralizing. It is estimated that chemicals for this purpose would cost $360 per year for a 25 MW plant and

$7,200 per year for a 500 MW plant. This corresponds to a unit cost of .0018 mils per KWH generated for a 90 percent capacity factor.

The following table (VIII-11) presents estimates for capital costs of pretreatment plants for Level C treatment of low volume and metal cleaning wastes for a coal-fired plant where sufficient land is not available.

ULTIMATE DISPOSAL

Costs For Land Destined Solid Wastes

Waste treatment processes discussed in this report are separation techniques which produce a liquid fraction suitable for discharge to the public sewer or reuse within the plant and a liquid or solid residue which requires ultimate disposal. Many of the processes produce sludges containing between 0.5 and 5.0 percent solids. These sludges are generally further dewatered at the site to 15 to 30 percent solids and then disposed off site. The following paragraphs discuss techniques and costs of dewatering and ultimate disposal applicable to steam electric power plants.

User Charges For Sewer Service Of the twenty-three plants visited in this study only 15 percent reported separate charges for sewer service, while 35 percent reported surcharges on their water bills for sewer service. Approximately fifty percent did not report charge for sewer service as they were municipal utilities whose internal billing systems did not allow for tracking of such charges.

The average charge for sewer service in this industry is $0.06/1000 l ($0.23/1000 gal).

Evaporation Ponds

Evaporation ponds are used by the industry as a method of ultimate disposal, particularly in the arid areas of the southwestern United States. The extensive land requirements make it unsuited for use in urban areas where plants discharging to POTWs are generally located.

Conveyance Off Site

The cost of this method of disposal is entirely related to the distance between plant and disposal site. Alterte methods of conveyance are trucks, railroads and pipelines. Trucking is most economical for distances under 50 miles. Costs are of the order of ($.01-$0.13 per 1000 liter) ($0.05-$0.50 per 1,000 gallon) miles exclusive of final disposal charges.

Table VIII-9 ESTIMATED CAPITAL COSTS CHEMICAL WASTES PRETREATMENT PLANT LEVEL C

	Installed Generating Capacity	
Description	25 MW	500 MW
Equalization Tank	$ 28,000	$ 115,000
Reactor	------	2,000
Clarifier	2,000	5,000
Pumps	1,000	4,000
Piping	2,000	5,000
Subtotal, major equipment	$ 33,000	$ 131,000
Installation & Foundations	17,000	65,000
Instrumentation	4,000	14,000
Subtotal, construction costs	$ 54,000	$ 210,000
Enginnering & Contingencies	16,000	60,000
Total, land not limited	$ 70,000	$ 270,000
Premium for limited land construction	20,000	80,000
Cost per KW IGC	$ 2.80	$ 0.54
Limited Land Premium	0.80	0.16
Estimated cost allottment, unlimited land		
Low volume wastes	2.40	0.60
Metal cleaning wastes	1.20	0.10

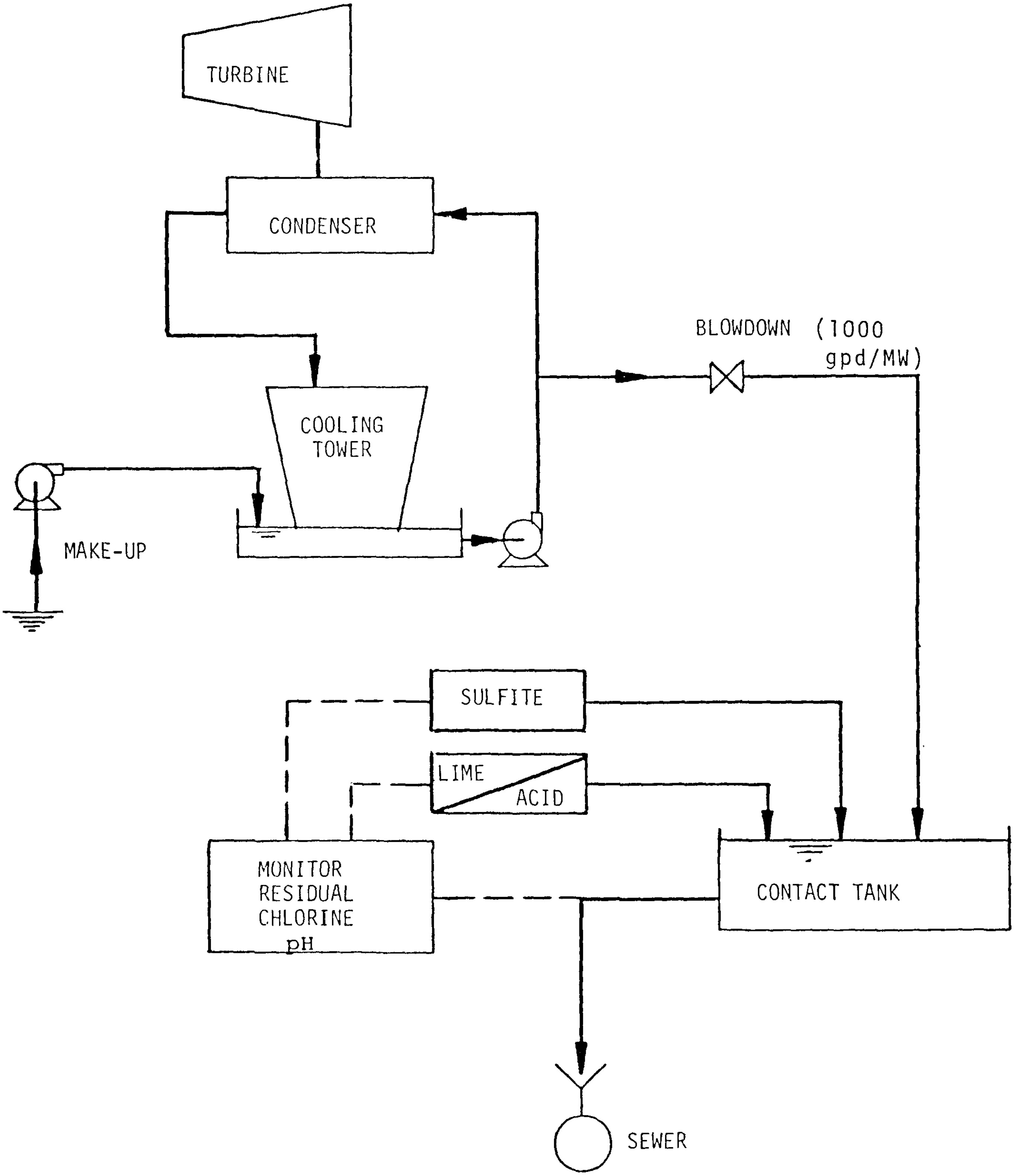


FIGURE VIII-3. Cooling Water System Blowdown Treatment For Level D Pretreatment

Table VIII-10 ESTIMATED CAPITAL COST COOLING WATER SYSTEM BLOWDOWN TREATMENT

Description	Installed Generating Capacity 25 MW	 500 MW
Contact Tank	$10,000	$40,000
Chemical Feed System	4,000	10,000
Piping	6,000	25,000
Subtotal, major equipment	$20,000	$75,000
Installation & foundations	10,000	37,000
Instrumentation	2,000	5,000
Subtotal, construction costs	$32,000	$117,000
Engineering & contingencies	9,600	35,000
Total Cost	$41,600	$153,000
Cost per KW IGC	$ 1.66	$ 0.31

Table VIII-11 ESTIMATED OPERATING COSTS COOLING WATER SYSTEM BLOWDOWN TREATMENT

Description	Installed Generating Capacity 25 MW	 500 MW
Operating Labor	$1,000	$4,000
Maintenance	1,200	6,000
Chemicals	500	10,000
Total	$2,700	$20,000

Landfills

Landfills are the most common method of disposal of solid wastes. Costs of disposal at landfills range from $1 to $9 per metric ton ($2-10 per ton). Recent federal regulations require landfills to provide leachate control, so that soluble components of the wastes cannot cause groundwater pollution.

ENERGY CONSIDERATIONS

In contrast to the effluent guidelines for thermal discharges, the promulgation of standards for pretreatment is not expected to involve significant energy requirements or to have a measurable impact on the energy production of the power plant. None of the treatment technologies described herein affect the power generating cycle and therefore do not require "retrofitting" to the extent that the performance of the plant is impaired. None of the processes involve a change of state and the only requirements for energy are for possible pumping needs. Even these needs are site dependent and many power plants may find it feasible to install the equipment in such a manner that repumping is not required.

For estimating purposes it has been assumed that a pretreatment plant handling low volume and metal cleaning wastes from a 25 MW generating plant would have a connected load of 5HP and that a similar plant for the 500 MW generating facility would have a connected load of 30 HP. Each plant would operate the equivalent of 800 hours per year, at full connected load. Under these conditions, the energy consumption by the waste treatment facilities would constitute about 0.02 percent of the generating capacity of the 25 MW generating plant and less than 0.01 percent of the generating capacity of the 500 MW plant.

Land Requirement

Many of the stations potentially affected by this study tend to be located in urbanized areas. Land requirements are important to such stations, as additional land may be difficult to purchase. Estimated land requirements to install Level C technology are given in the table below:

Station Size MW, IGC	Estimated Land Requirement, Acres
10	0.2
25	0.3
37	0.4

345	1.1
500	1.6

Land estimates are based on usage of tanks for equalization, mixing, settling, etc., and do not include credits for stacked construction. They contain space allowances for equipment, pumps, piping, foundation and electrical equipment and include treatment equipment for low-volume, metal cleaning and cooling tower wastes. If basins are used for equalization, etc., then land usage is expected to double. If stacked construction is employed, then land usage is expected to decrease by 67 percent. Land requirements need not be a problem, as treatment modules can be erected above existing generating equipment using stacking procedures.

SECTION IX

BEST PRACTICABLE PRETREATMENT TECHNOLOGY

After careful consideration of the information in this document and the draft financial impact study, pretreatment standards were developed. The best practicable pretreatment technology required to comply with these standards includes (1) oil skimming to reduce oil and grease in the plant's combined discharge to the POTW to less than 100 mg/l, and (2) lime precipitation to reduce copper in the metal cleaning wastes to less than 1 mg/l.

The methodology employed in the development of the pretreatment standards and the selection of the best practicable pretreatment technology is delineated below:

A detail survey was conducted to determine the number of plants affected by the pretreatment standards. Some of the plants from this population were visited and sampled. Plants were visited to determine whether significant differences exist between these power plants and power plants which discharge directly into navigable waters. Further, various waste streams were sampled from representative power plants to determine the type and level of pollutants. In defining the characteristics of various waste streams, data from the site visits and sampling program were used in conjunction with information in the development document for effluent limitations guidelines for this industry dated October 1974 and other sources. The compatibility of each raw waste characteristic with municipal treatment works was then considered. The constituents of the wastewaters which should be subject to limitations were identified.

The control and treatment technologies were identified. This included an identification of each distinct control and treatment technology, including both in-plant and end-of-process technologies, which is existent or capable of being designed. It also included an identification of the effluent level resulting from the application of each of the technologies. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, were identified. The energy requirements of the control and treatment technology were determined as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology reflected the application of the recommended pretreatment technologies.

In identifying such technologies, various factors were considered. These included the total cost of application of technology, the age and size of facilities involved, the fuel used, the mode of operations, the engineering aspects of the application of various types of control techniques, non-water quality environmental factors (including energy requirements) and other factors.

The data upon which the above analysis was performed included EPA sampling and inspections, consultant and EPA reports, industry submissions, and other sources.

(2) Summary of conclusions with respect to the general unit subcategory (Subpart A), small unit subcategory (Subpart B), old unit subcategory (Subpart C) and area runoff subcategorization (Subpart D) of the steam electric power generating point source category.

(i) Categorization

It is determined that all the facilities discharging into POTW should be subject to the same pretreatment standards. The standards for the general unit subcategory, small unit subcategory and old unit subcategory are the same and the pretreatment standards for the area runoff subcategory is different because of the nature of its discharge. Many factors were considered in this determination, but the largest contributing factors are (1) the production process, (2) the type and level of pollutants, (3) the treatability of wastewaters, and (4) the cost of the application of such technologies.

(ii) Waste characteristics

There are two different types of waste produced by steam electric power plants. The first type consists of the chemical wastes which originate from different processes and operations within a plant. These wastes are highly variable from plant to plant, depending on fuel, raw water quality, processes used in the plant and other factors. The known significant pollutants and pollutant properties from these wastes include pH, total suspended solids, iron, copper, nickel, zinc, chromium, oil and grease, and chlorine.

The second type of waste consists of the waste heat produced by the plant and disposed to the environment through the cooling water system.

(iii) Origins of wastewater pollutants

Wastewater streams from power plants can be classified into (1) metal cleaning wastes, (2) cooling system wastes, (3) boiler blowdown, (4) ash transport water, and (5) low volume waste.

Metal cleaning wastes are those wastes which are derived from cleaning of metal process equipment. These equipment include, but are not limited to, boiler tube, boiler fireside, and air preheater. Pollutants and pollutant properties in these wastes include oil and grease, iron, copper, nickel, zinc, total suspended solids, chromium and pH.

All condenser cooling systems can be classified as (1) once-through or (2) recirculating. Biocides such as chlorine or hypochlorites are usually added to once-through cooling water to minimize biological growth within the condenser and may, therefore, be discharged. The wastes from the recirculating cooling system include chemical additives to control growth of organisms (such as chlorine hypochlorites and organic chromates), chemical additives to inhibit corrosion (such as organic phosphates, chromates and zinc salts), and material present in the intake waters (but at a much higher concentration due to evaporative loss).

Boiler blowdown wastes normally have a high pH and high dissolved solids (except high pressure boiler). Phosphates which are used to precipitate the calcium and magnesium salts are also found in boiler blowdown.

One of the products of the combustion of coal and oil is ash. These ashes are sometimes transported by water to a settling pond or basin. Some or all of the water from the settling pond or basin may be discharged. The chemical characteristic of ash handling wastewater is basically a function of the fuel burned. The pollutants and pollutant properties in the ash handling wastes from coal fired plants include TSS, pH, iron, aluminum, mercury and oil and grease. TSS, pH, oil and grease, and sometimes vanadium are found in the ash handling wastes from oil fired plants.

Area runoff are the product of drainage from rainfall. This waste stream may contain TSS and oil and grease. Runoff from coal pile may also contain iron, high or low pH (depending upon the type of coal), copper, zinc and manganese.

Low volume wastes include ion exchange water treatment, water treatment evaporative blowdown, laboratory and sampling streams, floor drainage, cooling tower basin cleaning, ash pollution device effluent and any aqueous power plant wastes which have not been mentioned. These wastes contain primraily TSS and oil and grease.

(iv) Treatment and control technologies

Wastewater treatment and control technologies have been studied for this industry to determine what is the best pretreatment technology.

The following discussions of treatment technologies provide the bases for the pretreatment standard. These discussions do not preclude the selection of other wastewater treatment alternatives which provide equivalent or better levels of treatment.

(a) Oil and Grease. Oil skimmers have been demonstrated to reduce oil and grease concentration to less than 20 mg/l, far less than the limitation established here. Most, if not all, of the power plants can comply with this requirement if they employ good housekeeping techniques.

(b) Copper. The treatment of metal cleaning wastes would consist of oil and grease skimming in the equalization tank, lime addition in the reactor (to attain a pH level of approximately 9) and sedimentation and clarification (to achieve a total suspended solids of 30 mg/l). Effluent concentrations of 1 mg/l total copper are achievable by the application of this technology. Numerous chemicals are also removed by this treatment. Pollutants significantly removed by this treatment include nickel, zinc and chromates.

It is emphasized that in-plant measures to recycle and reuse wastewater to minimize discharge to municipal treatment works are included as part of the recommended pretreatment technology.

The pretreatment technology described above for the removal of copper requires disposal of the pollutants removed from wastewaters in the form of sludge. In order to insure long-term protection of the environment, special consideration of disposal sites must be made. All landfill sites where such hazardous wastes are disposed should be selected so as to prevent horizontal and vertical migration of these contaminants to ground or surface waters. In cases where geologic conditions may not reasonably ensure this, adequate legal and mechanical precautions (e.g., impervious liners) should be taken to ensure long term protection to the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of legal jurisdiction.

(v) Determination of incompatibility

Characteristics of waste streams described above were analyzed for incompatibility with POTW. Factors considered in determining incompatibility include (1) susceptibility of the pollutant to treatment by a secondary treatment system, and (2) interference of the pollutant with the operation of the POTW.

Copper, nickel and zinc from the metal cleaning wastes were found to be incompatible because (1) they can interfere with the operation of the POTW, (2) they may not be adequately treated, and (3) they pose a threat to the receiving waters beyond and to plants grown on soil treated with sludge from the POTW. Pretreatment standard for copper from the metal cleaning wastes of 1 mg/l is imposed. Limitations are not imposed for nickel and zinc because they are indirectly controlled through the regulation of copper. In certain cases, copper may not be present in significant quantity, but nickel and zinc will still be present in high concentrations. In such cases, it will be necessary for individual POTW operators to regulate nickel and zinc to levels which are achievable via lime precipitation.

Oil and grease from power plants is primarily petroleum based. This type of oil and grease is less biodegradable in secondary plants than oil and grease of vegetable and animal origin. Pretreatment standard of 100 mg/l of oil and grease is imposed to ensure (1) the proper operation of the biological treatment system, (2) adequate treatment by the POTW, and (3) proper transport of wastes to the treatment system.

Pretreatment standards other than those described above and the general standards carried over from 40 CFR 128 is determined not to be necessary at the present time.

(vi) Cost estimates for control of wastewater pollutants

Cost information was obtained from engineering firms, available literature, development documents for effluent limitation guidelines (October, 1974) for this industry, and from plants contacted. User charge data were obtained from power plants and POTW.

The utilities affected by the regulation should have little or no trouble in obtaining the capital necessary for the construction of the pretreatment facilities. The annual revenue requirements are projected to increase the cost of electricity by .11 mills/kwh at the affected plants.

(vii) Energy requirements and non-water quality environmental impacts.

The major non-water quality consideration which may be associated with the recommended pretreatment technologies is the generation of metals-bearing solid wastes. In most cases, these wastes will be landfilled.

Other non-water quality aspects, including energy, noise and air pollution, will not be perceptibly affected.

SECTION X

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SECTION XI

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SECTION XII

GLOSSARY

Absolute Pressure. The total force per unit area measured above absolute vacuum as a reference. Standard atmospheric pressure is 101,326 N/M2 (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).

Anion. The charged particle in a solution of an electrolyte which carries negative charge.

Anthracite. A hard natural coal of high luster which contains little volatile matter.

Approach Temperature. The difference between the exit temperature of water from a cooling tower, and the wet bulb temperature of the air.

Ash. The solid residue following combustion of a fuel.

Ash Sluice. The transport of solid residue ash by water flow in a conduit.

Backwash. Operation of a granular fixed bed in reverse flow to wash out sediment and reclassify the granular media.

Bag Filters. A fabric type filter in which dust laden gas is made to pass through woven fabric to remove the particulate matter.

Base. A compund which dissolves in water to yield hydroxyl ions (OH-).

Base-Load Unit. An electric generating facility operating continously at a constant output with little hourly or daily fluctuation.

Biocide. An agent used to control biological growth.

Bituminous. A coal of intermediate hardness containing between 50 and 92 percent carbon.

Blowdown. A portion of water in a closed system which is wasted in order to prevent a built-up 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 of boiler heat exchange elements exposed to the hot combustion products.

Boiler Scale. An incrustation of salts deposited 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 1000 to 10,000 mg per liter.

Brine. Water saturated with a salt.

Bus Bar. A conductor forming a common junction between two or more electric circuits. A term commonly used in the electric utility industry refer to electric power leaving a station boundary. Bus bar costs would refer to the cost per unit of electrical energy leaving the station.

Capacity Factor. The ratio of energy actually produced to that which would have been produced in the same period had the unit been operated continously rated capacity.

Cation. The charged particles in solution of an electrolyte which are positively charged.

Carbonate Hardness. Hardness of water caused by the presence of carbonates and bicarbonates of calcium and magnesium.

Circulating Water Pumps. Pumps which deliver cooling water to the condensers of a power plant.

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 suspended matter.

Closed Circulating Water System. A system which passes water through the condensers, then through an articial 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 contractural 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.

Cooling Canal. A canal in which warm water enters at one end, is cooled by contact with air, and is discharged at te other end.

Cooling Lake. See Cooling Pond.

Cooling Pond. A body of water in which warm water is cooled by contact with air, and is either discharged or returned for reuse.

Cooling Tower. A configured heat exchange device which transfers reject 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 Ihibitor. A chemical agent which slows down or prohibits a corrosion reaction.

Counterflow. A process in which two media 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. In this report, a facility operating between 2000 and 6000 hours per year.

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 Furnace. Molten slag forms on the cyclinder walls, and flows off for removal.

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.

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.

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.

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 or Conduit. A section of pipe or conduit from the condenser discharge to the point of discharge into receiving waters or cooling device.

Drift. Entrained water carried from a cooling device by the exhaust air.

Dry Bottom Furnace. Refers to a furnace in which the ash is collected as a dry solid in hoppers at the bottom of the furnace, and removed from the furnace in this state.

Dry Tower. A cooling tower in which the fluid to be cooled flows within a closed system. This type of tower usually uses finned or extended 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.

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 suspened solids from water, consisting of granular material placed in horizontal layers and capable of being cleaned hydraulically by reversing the direction of the flow.

Filtration. The process of passing a liquid through a filtering medium for the removal of suspned or colloidal matter.

Fireside Cleaning. Cleaning of the outside surface of boiler tubes and combustion chamber refractories to remove deposits formed during the combustion.

Flue Gas. The gaseous products resulting from the combustion process after passage through the boiler.

Fly Ash. A portion of the non-combustible 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.

Generation. The conversion of chemical or mechanical energy into electrical energy.

Heat Rate. The fuel heat input (in Joules or BTU) 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 lb 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 a solid but no radical change in the structure of the solid.

Lignite. A carbonaceous fuel ranked between peat and coal.

Makeup Water Pumps. Pumps which provide water to replace that lost by evaporation, seepage, and blowdown.

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.

Mill. One thousandth of a dollar.

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, slorry pipeline or truck.

Mole. The molecular weight of substance expressed in grams (or pounds).

Name Plate. See Nominal Capacity.

Natural Draft Cooling Tower. A cooling tower through which air is circulated by 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 hydroxyl ions are about equal.

New Source. Any source, the construction of which is commenced after the publicated of proposed Section 306 regulations.

Nominal Capacity. Name plate - design rating of a plant, or specific piece of equipment.

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.

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.

Osmosis. The process of diffusion of a solvent thru a semi-permeable membrane from a solution of lower to one of higher concentration.

Osmotic Pressure. The equilibrium pressure differential across a semi-permeable membrane which separates a solution of lower from one or higher concentration.

Oxidation. The addition of oxygen to a chemical compund, generally, any reaction which involves the loss of electrons from an atom.

Packing (Cooling Towers). A media providing large surface area for the purpose of enhancing mass transfer, usually between a gas or vapor, and a liquid.

Precipitation. A pheonomenon 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 by absorbing heat from the products of combustion.

Peak-load Plant. A generating facility operated only during periods of maximum demand, in this report is is a facility operating less than 2000 hours per year.

Penalty. A sum to be forfeited, or a loss due to some action.

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.

Powerplant. Equipment that produces electrical energy, generally by conversion from heat energy produced by chemical or nuclear reaction.

Psychrometric. Refers to air-water vapor mixtures and their properties. A psychrometric charg 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.

Pump Runout. The tendency of a centrifugal pump to deliver more than its design flow when the system resistance falls below the design head.

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.

Rankine Cycle. THe thermodynamic cycle which is the basis of the steam-electric generating process.

Rank of Coal. A classification of coal based upon the fixed carbon on a dry weight basis and the heat value.

Recirculation System. Facilities which are specifically designed to divert the major portion of the cooling water discharge back to the cooling water intake.

Recirculation. Return of cooling water discharge back to the cooling water intake.

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.

Relative Humidity. Ratio of the partial pressure of the water vapor to the vapor pressure of water at air temperature.

Reinjection. To return a flow or portion of flow, into a process.

Reverse Osmosis. The process of diffusion of a solvent thru a semi-perable membrane from a solution of higher to one or lower concentration, affected by raising the pressure of a more concentrated solution to above the osmotic pressure.

Reduction. A chemical reaction which involes the addition of electrons to an ion to decrease its positive valence.

Saline Water. Water containing salts.

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 the water vapor is in equilibrium with the 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 heat transfer surfaces which inhibit the passage of heat through these surfaces.

Scrubber. A device for removing particles and/or objectionable gases from a stream of gas.

Secondary Treatment. The treatment of sanitary wastes water 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 compunds which are added to water systems to prevent the formation of scale by holding the insoluble compunds in suspension.

Service Water Pumps. Pumps providing water for auxiliary plant heat exchangers and other uses.

Slag Tap Furnace. Furnace in which 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 whwere 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 start up time.

Spray Module (Powered Spray Module). A water cooling device consisting of a pump and spary nozzle or nozzles mounted on floats and moored in the body of water to be cooled. Heat is transfered principally by evaporation from the water drops as they fall through the air.

Station. A plant comprising one or several units for the generation of power.

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/m2 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.

Thermal Efficiency. The efficiency of the thermodynamic cycle producing work from heat. The ration of usable energy to heat input expressed as percent.

Thickening. Process of increasing the solids content of sludge.

Total Dynamic Heat (TDH). Total energy provided by a pump consisting of the difference in elevation between the suction and dischage levels, plus losses due to unrecovered velocity heads and friction.

Turbidity. Presence of suspended matter such as organic or inorganic material plantkton or other microscopic organisms which reduce the clarity of the water.

Turbine. A device used to convert the energy of steam or gas into rotation mechanical energy and used as prime mover to drive electric generation.

Unit. In steam electric generation, the basic system for power generation consiting of a boiler and its associated turbine and generator with the required auxiliary equipmet.

Utility. Public utility. A company, either investorowned 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, give 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 continous stream of air.

Wet Scrubber. A device for the collection of particulate matter from a gas stream and/or absorption of noxious gases from the stream.

Zeolite. Complex sodium aluminum silicate materials, which have ion exchange properties and were the original ion exchange materials before synthetic resins were processed.

APPENDIX A

STATISTICAL ANALYSIS OF HISTORICAL DATA

Effluent pretreatment standards achievable by steam electric power plants discharging their wastewater effluents into publicly-owned treatment facilities were determined from statistical analysis of historical data describing the pollutants concentration over extended periods of time. Of the three plants analyzed only one provides partial pretreatment which includes flow equalization, oil removal, and settling. The remaining two plants discharge untreated waste. This appendix describes the statistical approach used and presents results of that analysis.

The statistical analysis was based on the assumption that the data are normally distributed, that is, their frequency of occurrence is fully defined by two statistical parameters: The mean X and the standard deviation s. Each set of data representing the variation of concentration of a particular pollutant in treated effluent was statistically examined to determine the mode of normal distribution that best describes its frequency of occurrence. Both arithmetic and logarithmic modes of normal distribution were considered. The degree of fit of the data to any particular mode was determined by calculating the coefficients of skewness and of kurtosis. The former measures the symmetry of the distribution diagram and the latter measures the height of the peak of the diagram relative to that of a normal curve. A perfect fit to normal distribution is indicated by a zero coefficient of skewness and a coefficient of kurtosis of three.

If neither the arithmetic nor the logarithmic modes of normal distribution describe the frequency of occurrence of a data set, a modified logarithmic mode was employed to "force" the data into normal distribution. This mode is referred to as the three-parameters logarithmic type of normal distribution. It is assumed that deviation from normal distribution occurs in the tails of the frequency curve where the probability of occurrence is very low. Thus, it is assumed that deviation of data from the perfect logarithmic mode of normal distribution is due to small sample size. The overall effect of this deviation is to increase the variance of the data set. The three-parameters approach is designed to remove this deviation in the tails by adding or subtracting a constant number, smaller than the first element of the data set, to each member of the sample. The exact value of the constant is determined by iterating a series of mathematical expressions designed to generate a zero coefficient of skewness and a value of approximately three for the coefficient of kurtosis.

The mathematical treatment of data was carried out by a computer program. Each set of data was initially read by the computer which sorted elements in ascending order. The computer then calculated the first four moments and the coefficients of skewness and kurtosis for each of the three modes of normal distribution. The statistical coefficients of the three-parameters logarithmic mode of normal distribution were determined by initially assigning an arbitrary constant to be added to each element of the data set. The computer calculated the coefficient of skewness and determined from its value whether the deviation from normal distribution occurred at the lower or upper tail of the diagram. A deviation in the lower tail was indicated by a negative value and the computer proceeded to correct it by adding to each of the elements half of the arbitary constant. A positive coefficient of skewness was corrected by subtracting half of the constant. This was repeated until a zero coefficient of skewness was obtained. The computer then calculated the percent cumulative of each element in the series and converted it to standard deviation expressed as probit (standard deviation plus five).

Based on the values of the coefficients of skewness and kurtosis the mode of normal distribution that best described the distribution of the data set was selected and the data were subjected to a least squares analysis as a function of the corresponding probits to determine the coefficients of regression (slope, intercept, and coefficient of determination). The regression line was used to determine the 99 percent confidence upper limits.

Table A-1 lists the mathematical expressions used to calculate the various statistical parameters. These are shown in Tables A-2 to A-6 for various pollutants discharged from three pants. Each of these tables shows the calculated values of the first four moments, and the coefficients of skewness and kurtosis, for each of the modes of normal distribution. Also shown in these tables are the constants used to normalize the distribution of the data, the coefficients of regression (slope, intercept, and coefficient of determination), and the 99 percent confidence limits. Plots of the best fit data and their regression lines are shown in Figures A-1 to A-19. The statistical parameters of the best fit data are summarized in Table A-7. The historical data analyzed are listed in Table A-8.

Water usage data listed in Section V of this report have also been statistically analyzed by the three modes of normal distribution. The results are listed in Table A-9 and plotted in Figures A-20 to A-23. In all of the water usage categories examined, the distribution of the data could be normalized by the three parameter approach. This is indicated by the numerical values calculated by the coefficients of determination which measure the "goodness of fit" of the regression line. The values were always greater than 90 percent.

The water usage data were also plotted on log-log paper against production rate to determine the effect of plant size on the quantity of water used. These plots are shown in Figures A-24 to A-27 and the coefficients of the statistical regression analysis expressed in logarithms are shown in Table A-10. The results indicate that based on the available data, there is no correlation between water usage in each of the categories and production rate, as indicated by the low values calculated for the coefficients of determination.

Table A-1. MATHEMATICAL EXPRESSIONS FOR DETERMINATION OF STATISTICAL PARAMETERS

First moment $$m_1 = \frac{1}{n} \sum_{i=1}^{n} X_i \text{ (mean)}$$

Second moment $$m_2 = \frac{1}{n} \sum_{i=1}^{n} X_i^2 - \overline{X}^2 \text{ (variance)}$$

Third moment $$m_3 = \frac{1}{n} \sum_{i=1}^{n} X_i^3 - \frac{3}{n} \overline{X} \sum_{i=1}^{n} X_i^2 + 2\overline{X}^3$$

Fourth moment $$m_4 = \frac{1}{n} \sum_{i=1}^{n} X_i^4 - \frac{4}{n} \overline{X} \sum_{i=1}^{n} X_i^3 + \frac{6}{n} \overline{X}^2 \sum_{i=1}^{n} X_i^2 - 3\overline{X}^4$$

Coefficient of skewness $$\gamma_1 = \frac{m_3}{m_2^{(3/2)}}$$

Coefficient of kurtosis $$\gamma_2 = \frac{m_4}{m_2^{2}}$$

Probit $$Q = \int_{X}^{\infty} \frac{e^{-t^2} dt}{2\pi}$$

$$X = t - \frac{C_0 + C_1 t + C_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} + (-(Q)\epsilon)$$

$$t = \sqrt{\ln \frac{1}{Q^2}}$$

$$P = X + 5$$

Slope

$$a_1 = \frac{\sum_{x=1}^{n} X_i P_i - \frac{\sum_{i=1}^{n} X_i \sum_{i=1}^{n} P_i}{n}}{\sum_{i=1}^{n} X_i^2 - \frac{{\sum_{i=1}^{n} X_i}^2}{n}}$$

Intercept

$$a_2 = \overline{P} - a_1 \overline{X}$$

$$\overline{P} = \frac{\sum_{i=1}^{n} P_i}{n}$$

Coefficient of determination

$$= \frac{\left[\sum_{i=1}^{n} X_i P_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} P_i\right]^2}{\left[\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}\right]\left[\sum_{i=1}^{n} P_i^2 - \frac{\left(\sum_{i=1}^{n} P_i\right)^2}{n}\right]}$$

X_i - the value of element i of a data set. $X_i = X_i$ for arithmetic mode, $X_i = \log X_i$ for logarithmic mode, and $X_i = \log (X_i + a)$ for three-parameters mode of normal distribution, where a is the added or subtracted constant.

n - number of elements in a data set

C_0 - 2.515517 d_1 - 1.432788

C_1 - 0.802853 d_2 - 0.189269

C_2 - 0.010328 d_3 - 0.001308

$\epsilon(Q) < 4.5 \times 10^{-4}$

Table A-2: STATISTICAL ANALYSIS OF HISTORICAL DATA (MG/L)

Plant No. 7308	Wastewater Source: Retention Pond						
Pollutant	Iron		Nickel			Silver	
Mode of Normal Distribution Statistical Parameter	Arithmetic	Logarithmic	Arithmetic	Logarithmic	Three Parameters Logarithmic	Arithmetic	Logarithmic
Mean	4.75	4.86	2.40	1.73	1.3	0.04	0.04
Variance	0.68	0.005	51214.64(1)	0.09(1)	0.60(1)	1.68(1)	0.02(1)
Third Moment	0.28	0.00	---	0.036(1)	0.00	-2.53(1)	-0.005(1)
Fourth Moment	0.77	0.00	---	0.026(1)	0.78(1)	6.64(1)	0.002(1)
Coeff. of Skewness	0.49	0.4	1.45(1)	1.21(1)	0.00(1)	-1.15(1)	-1.15(1)
Coeff. of Kurtosis	1.63	1.51	3.18(1)	2.87(1)	2.16(1)	2.33(1)	2.33(1)
Correction Constant					-0.92		
Slope	1.88				1.15(1)	1.58(1)	
Intercept	-4.67				-4.17(1)	-3.52(1)	
Coeff. of Determination	0.91				0.97(1)	0.33(1)	
99% Confidence Limit	6.67				3.1	0.07	

(1) calculated with data x 100

Table A-3. STATISTICAL ANALYSIS OF HISTORICAL DATA (MG/L)

Plant No. 7308 Wastewater Source: Cooling Tower Basin

Pollutant	Iron		Copper			Chromium		
Mode of Normal Distribution / Statistical Parameter	Arithmetic	Logarithmic	Arithmetic	Logarithmic	Three Parameters Logarithmic	Arithmetic	Logarithmic	Three Parameters Logarithmic
Mean	5.27	3.92	0.34	0.64	0.58	2.90	2.08	2.03
Variance	10.55	0.12	2535.43	0.24	0.72	605.02(1)	0.12(1)	0.15(1)
Third Moment	12.70	-0.02	190480.68	0.14	0.00	20240.16(1)	0.000(1)	0.00(1)
Fourth Moment	255.14	0.03	---	0.17	1.31	---	0.03(1)	0.05(1)
Coeff. of Skewness	0.37	-0.63	1.49	1.22	0.00	1.36(1)	0.14(1)	0.00(1)
Coeff. of Kurtosis	2.29	2.05	3.23	2.96	2.48	3.76(1)	2.23(1)	2.29(1)
Correction Constant					-0.04			-0.14
Slope	4.26				1.19			0.507(1)
Intercept	-16.0				-5.21			-1.25(1)
Coeff. of Determination	0.96				0.87			0.96(1)
99% Confidence Limit	12.83				0.8			2.93

(1) calculated with data x 100

Table A-3. STATISTICAL ANALYSIS OF HISTORICAL DATA (MG/L) (CONTINUED)

	Lead			Zinc			pH(1)		
Mode of Normal Distribution / Statistical Parameter	Arithmetic	Logarithmic	Three Parameters Logarithmic	Arithmetic	Logarithmic	Three Parameters Logarithmic	Arithmetic	Logarithmic	Three Parameters Logarithmic
Mean	0.29	0.2	0.33	3.9	1.38	0.8	6.4	6.3	6.4
Variance	543.1	0.15	0.08	369961.0(2)	0.33(2)	1.09(2)	20.5(3)	0.001(3)	0.0(3)
Third Moment	11025.36	-0.02	0.00	----	0.18(2)	0.0(2)	-129.5(3)	0.00(3)	0.0(3)
Fourth Moment	712419.5	0.04	0.01	---	0.26(2)	2.51(2)	1640.0(3)	0.00(3)	0.0(3)
Coeff. of Skewness	0.87	-0.29	0.00	1.74(2)	10.94(2)	0.0(2)	-1.39(3)	-1.5(3)	0.0(3)
Coeff. of Kurtosis	2.41	2.02	2.00	4.51(2)	2.34(2)	2.1(2)	3.89(3)	-3.43(3)	-4.03(3)
Correction Constant			0.05			-0.4			8.02
Slope			0.37			1.39(2)			0.01(3)
Intercept			-0.41			-5.31(2)			2.07(3)
Coeff. of Determination			0.93			0.98(2)			0.78(3)
99% Confidence Limit			0.45			3.51			6.4

(1) pH units

(2) calculated with data x 100

(3) calculated with data x 10

Table A-4. STATISTICAL ANALYSIS OF HISTORICAL DATA (MG/L)

Plant No. 8696 Wastewater Source: Demineralizer

Pollutant	pH (1)			Suspended Solids			BOD_5		COD		
Mode of Normal Distribution / Statistical Parameter	Arith-metic	Loga-rithmic	Three Para-meters Loga-rithmic	Arith-metic	Loga-rithmic	Three Para-meters Loga-rithmic	Arith-metic	Loga-rithmic	Arith-metic	Loga-rithmic	Three Para-meters Loga-rithmic
Mean	5.52	4.16	4.26	32.67	12.02	8.55	2.53	0.25	28.83	23.44	22.27
Variance	14.13	0.10	0.09	4053.73	0.26	0.70	3.21	0.18	424.58	0.07	0.11
Third Moment	26.64	-0.001	0.00	737828.37	0.19	0.00	3.1	-0.05	12699.82	0.007	
Fourth Moment	319.44	0.02	0.015		0.27	1.68	23.98	0.08	718259.0	0.015	0.03
Coeff. of Skewness	0.50	-0.05	0.00	2.86	1.42	0.00	0.54	-0.75	1.45	0.39	0.00
Coeff. of Kurtosis	1.60	1.78	1.71	10.35	3.86	3.40	2.32	2.60	3.98	2.69	2.95
Correction Constant			0.204			-3.54					-3.65
Slope			0.35			0.96	2.07				0.38
Intercept			-1.09			-4.09	-7.82				-0.64
Coeff. of Determination			0.93			0.92	0.94				0.94
99% Confidence Limit			9.26			97.56	6.89				28.20

(1) pH units

Table A-5. STATISTICAL ANALYSIS OF HISTORICAL DATA (MG/L)

Plant No. 8696 Wastewater Source: Cooling tower blowdown

Pollutant	$pH^{(1)}$		Suspended Solids			BOD_5		COD		
Mode of Normal Distribution / Statistical Parameter	Arith-metic	Loga-rithmic	Arith-metic	Loga-rithmic	Three Para-meters Loga-rithmic	Arith-metic	Loga-rithmic	Arith-metic	Loga-rithmic	Three Para-meters Loga-rithmic
Mean	7.46	0.87	14.25	13.48	13.59	2.54	2.36	26.55	25.70	26.40
Variance	0.08	0.0003	18.35	0.017	0.013	0.84	0.03	17.33	0.09	0.0007
Third Moment	0.01	0.00	48.30	-0.00018	0.00	-0.04	-0.003	-6.64	-0.06	0.00
Fourth Moment	0.007	0.00	926.85	0.00079	0.0005	1.2	0.002	498.25	0.06	0.00
Coeff. of Skewness	0.6	0.47	0.61	-0.083	0.00	-0.05	-0.51	-0.09	-2.52	0.00
Coeff. of Kurtosis	1.13	9.42	2.75	2.72	2.65	1.683	2.11	1.66	8.35	0.00
Correction Constant					1.54					38.74
Slope	0.33				0.13		0.20			0.03
Intercept	5.83				0.50		-0.64			1.64
Coeff. of Determination	0.92				0.96		0.96			0.96
99% Confidence Limit	8.11				15.39		3.85			27.55

(1) pH units

Table A-6. STATISTICAL ANALYSIS OF HISTORICAL DATA (MG/L)

Plant No. 8392	Wastewater Source: Cooling tower			Boiler		
Pollutant	Chromate			Phosphate		
Mode of Normal Distribution / Statistical Parameter	Arithmetic	Logarithmic	Three Parameters Logarithmic	Arithmetic	Logarithmic	Three Parameters Logarithmic
Mean	14.94	14.46	14.53	17.1	16.59	16.51
Variance	7.31	0.05	0.01	13.98	0.009	0.002
Third Moment	32.69	0.0002	0.00	10.86	-0.0003	0.00
Fourth Moment	394.28	0.0001	0.001	569.44	0.0002	0.00
Coeff. of Skewness	1.65	0.66	0.00	0.20	-0.36	0.00
Coeff. of Kurtosis	7.37	5.63	5.37	2.90	2.82	-3.10
Correction Constant			-5.62			19.99
Slope			0.12			0.05
Intercept			0.34			1.31
Coeff. of Determination			0.77			0.97
99% Confidence Limit			16.24			17.18

Table A-7. STATISTICAL PARAMETERS SUMMARY FOR BEST FIT DATA (MG/L)

Source	Cooling Tower Blowdown (Plant 8696)			Demineralizer (Plant 8696)		
Parameter	Statistical Mode	Concentration Mean	99% Confidence Limit	Statistical Mode	Concentration Mean	99% Concentration Limit
pH	Arithmetic	7.46	8.11	3-parameter	4.26	9.26
Suspended Solids	3-Parameter	13.59	15.39	3-parameter	8.55	97.56
BOD_5	Logarithmic	2.36	3.85	Arithmetic	2.53	6.89
COD	3-Parameter	26.40	27.55	3-parameter	22.27	28.20
Source	Cooling Tower Blowdown (Plant 8392)			Boiler (Plant 8392)		
Parameter Chromate	3-parameter	14.53	16.24	—	—	—
Phosphate	—	—	—	3-parameter	16.51	17.78

Source	Cooling Tower Basin (Plant 7308)		
Parameter	Statistical Mode	Concentration Mean	99% Confidence Limit
Fe	Arithmetic	5.27	12.83
Cu	3-parameter	0.58	0.80
Cr	3-parameter	2.03	2.93
Pb	3-parameter	0.33	0.45
Zn	3-parameter	0.8	3.23
pH	3-parameter	6.4	6.4
Source	Retention Pond		
Parameter			
Fe	Arithmetic	4.75	6.67
Ni	3-parameter	1.3	3.1
Ag	Arithmetic	0.04	0.03

Table A-8. HISTORICAL DATA (MG/L)

Plant No. 8696

Cooling Tower Blowdown

pH	7.27, 7.94, 7.08, 7.4, 7.26, 7.72, 7.14, 7.5, 7.33, 7.72, 7.4, 7.97, 7.14, 7.25, 7.35, 7.23, 7.65, 7.39, 7.98, 7.35
SS	11.0, 23.0, 23.0, 14.0, 15.6, 12.0, 7.2, 13, 11.6, 16.0, 19.6, 13.5, 17.6, 11.0, 12.0, 8.4
BOD_5	2.7, 3.0, 1.0, 2.1, 3.7, 3.7, 3.3, 3.8, 3.9, 2.9, 3.2, 2.5, 2.2, 1.9, 1.6, 1.3, 1.4, 1.6
COD	24.0, 29.0, 27.0, 12.0, 33.0, 30.0, 30.0, 31.0, 2.2, 24.0, 23.0, 21.0, 20.0

Demineralizer Backwash

pH	1.0, 5.77, 1.95, 3.23, 2.86, 3.26, 9.52, 2.16, 6.42, 2.72, 10.10, 9.87, 11.65, 9.8, 1.72, 12.0, 2.7, 2.78
SS	96.0, 8.4, 11.0, 9.6, 5.6, 6.4, 4.0, 5.2, 19.0, 10.8, 3.6, 8.6, 84.0, 8.0, 264.0, 6.4, 4.8
BOD_5	4.7, 0.3, 0.2, 0.7, 0.9, 1.0, 2.7, 5.8, 6.2, 3.2, 3.0, 2.8, 3.3, 2.1, 3.8, 1.6, 0.8;
COD	22.0, 19.0, 21,0, 7.0, 13.0, 22.0, 22.0, 24.0, 39.0, 39.0, 13.0, 71.0, 57.0, 18.0, 20.0, 83.0, 18.0, 11.0

Plant No. 8392

Cooling Tower

Chromate	16,0, 24,0, 18.0, 14.0, 16.0, 14.0, 14.0, 14.0, 14.0, 12.0, 10.0, 14.0, 14.0, 16.0, 14.0, 14.0, 16.0, 16.0, 14.0

Boiler

Phosphate	15.0, 18.0, 16.0, 26.0, 19.0, 15.0, 18.0, 13.0, 20.0, 17.0, 14.0, 12.0, 10.0, 20.0, 13.0, 21.0, 19.0, 18.0

Plant No. 7308

Retention Pond

Fe	4.0, 179.0, 4.0, 6.0, 5.0
Ni	1.35, 6.9, 1.1, 1.72, 0.95
Ag	0.05, 0.05, 0.05, 0.02

Cooling Tower Basin

Fe	11.4, 7.25, 5.75, 1.0, 7.5, 3.5, 4.5, 1.3
Cu	0.05, 1.35, 0.12, 0.1, 0.1
Cr	2.0, 4.0, 4.0, 8.6, 1.1, 0.55, 1.5, 1.5
Pb	0.25, 0.75, 0.05, 0.6, 0.25, 0.25, 0.18, 0.06
Zn	7.85, 18.75, 0.8, 0.7, 0.45, 1.75, 0.54, 0.41

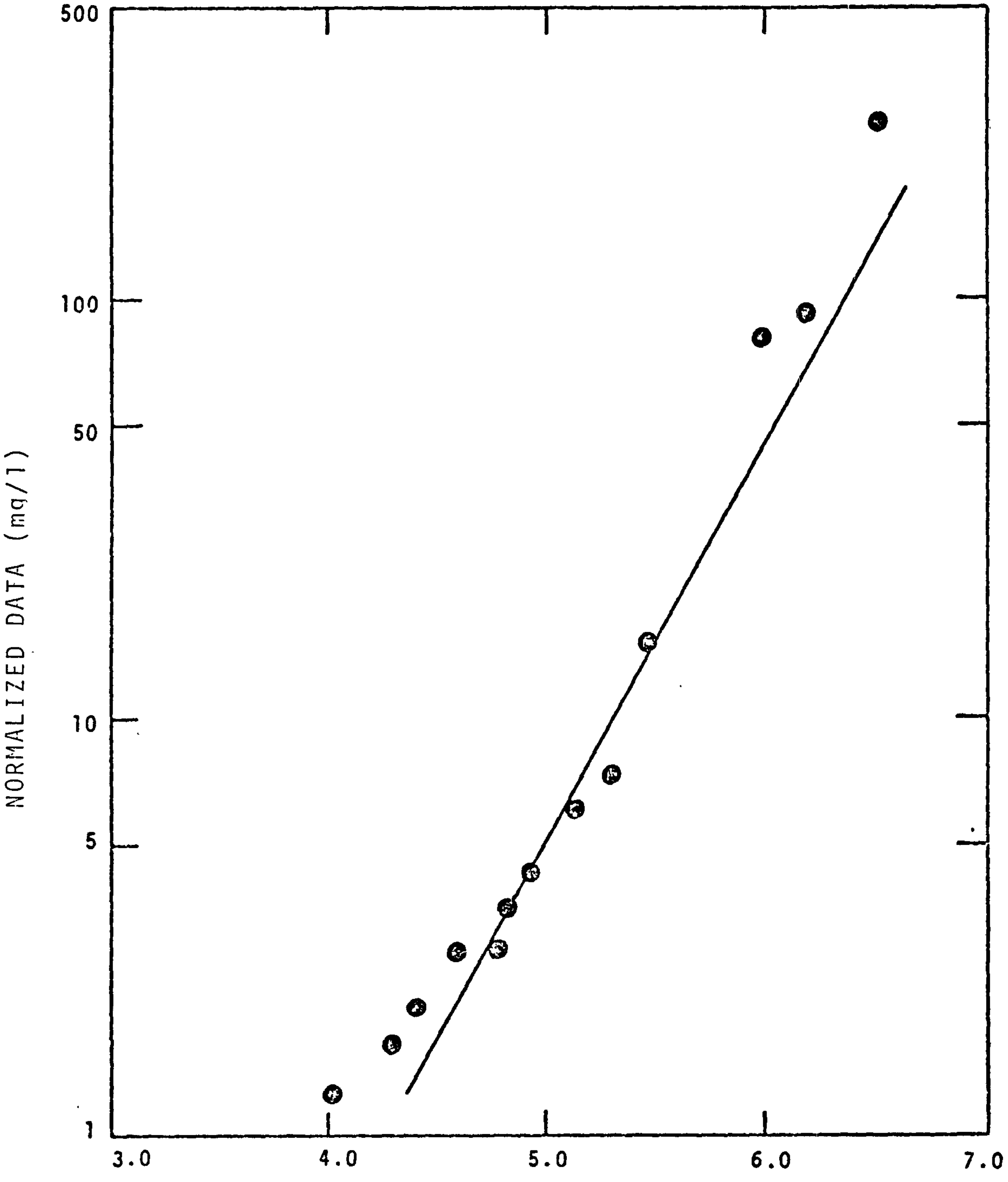

FIGURE A-1. Normal Distribution Diagram for Supsended Solids Concentration in Wastewaters from Demineralizer (Plant 8696)

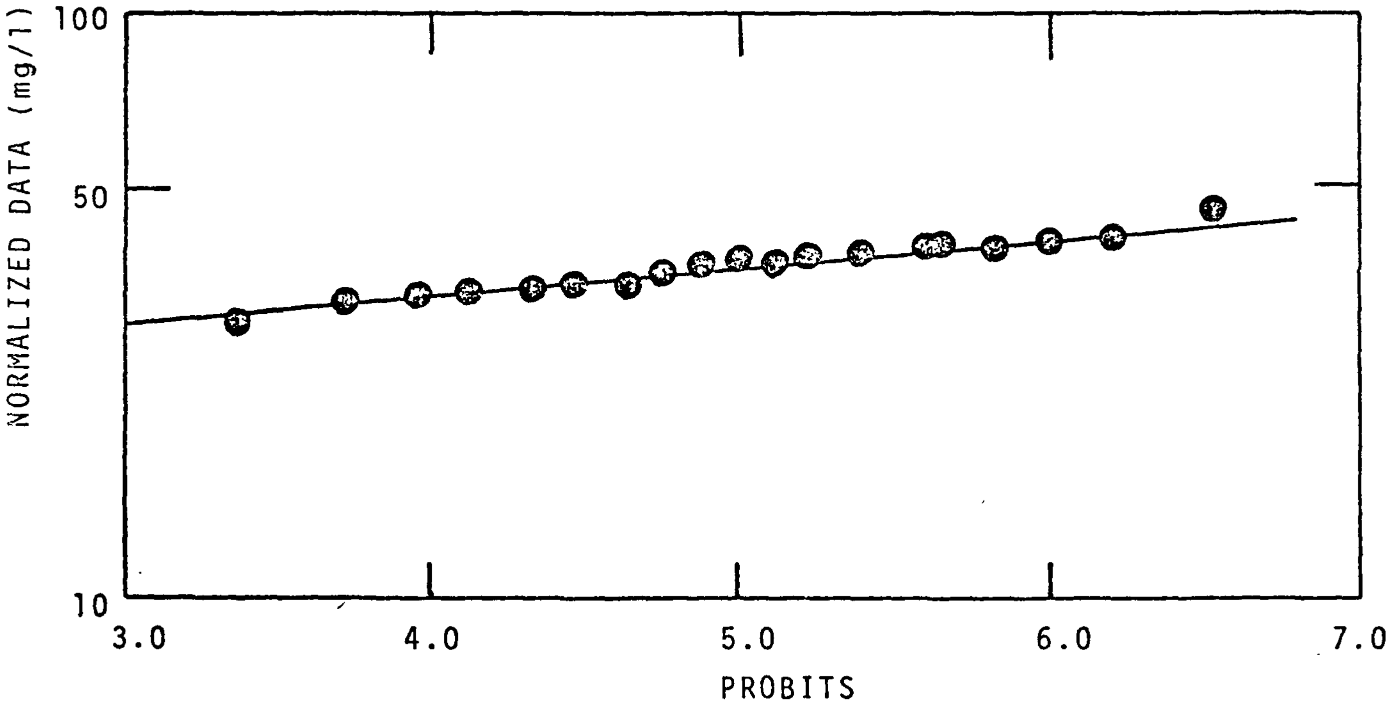

FIGURE A-2. Normal Distribution Diagram for Phosphates Concentration In Boiler Blowdown (Plant 8696)

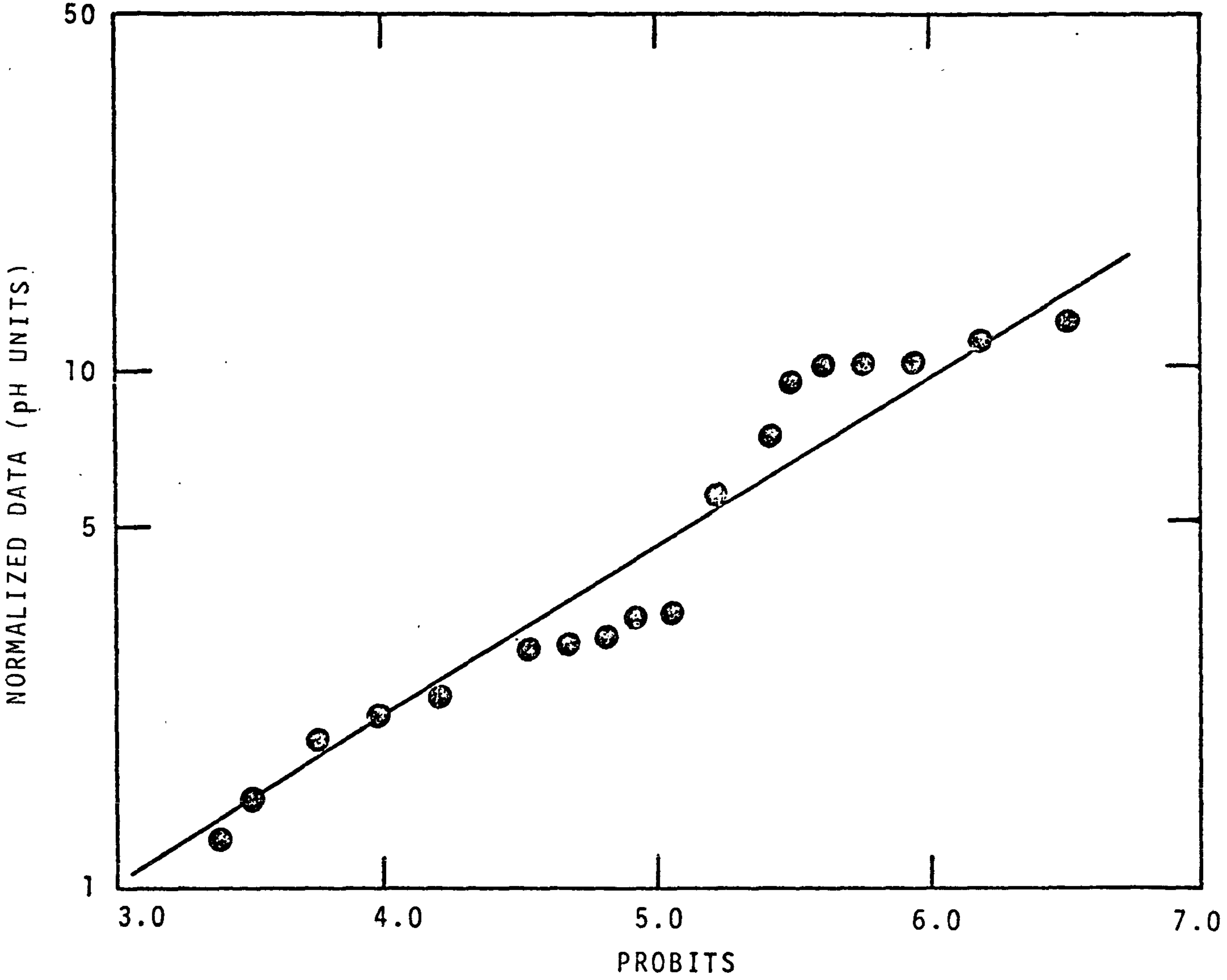

FIGURE A-3. Normal Distribution Diagram for pH Concentration In Wastewater from Deminealizer (Plant 8696)

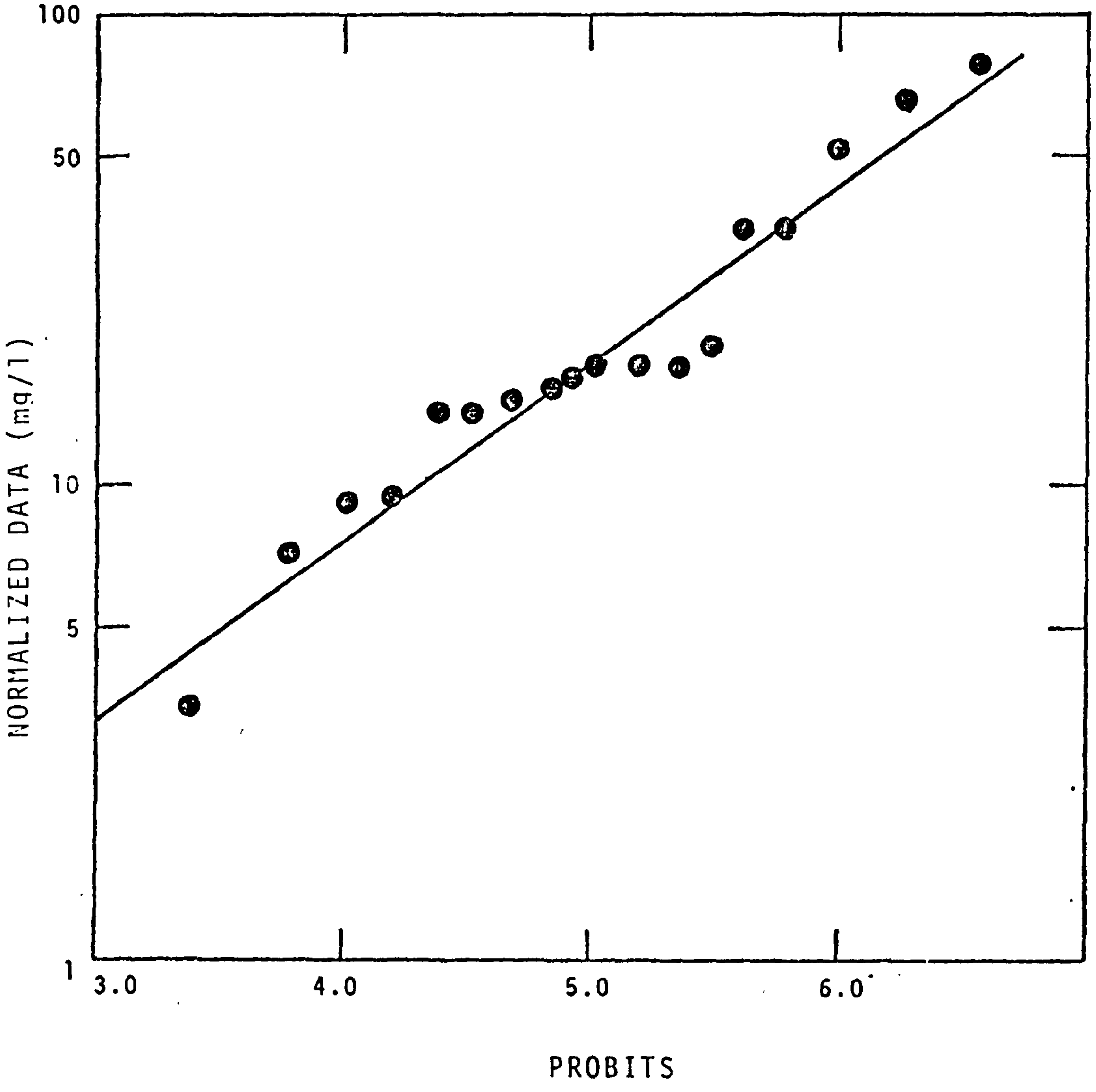

FIGURE A-4. Normal Distribution Diagram for COD Concentration In Wastewater From Demineralizer (Plant 8696)

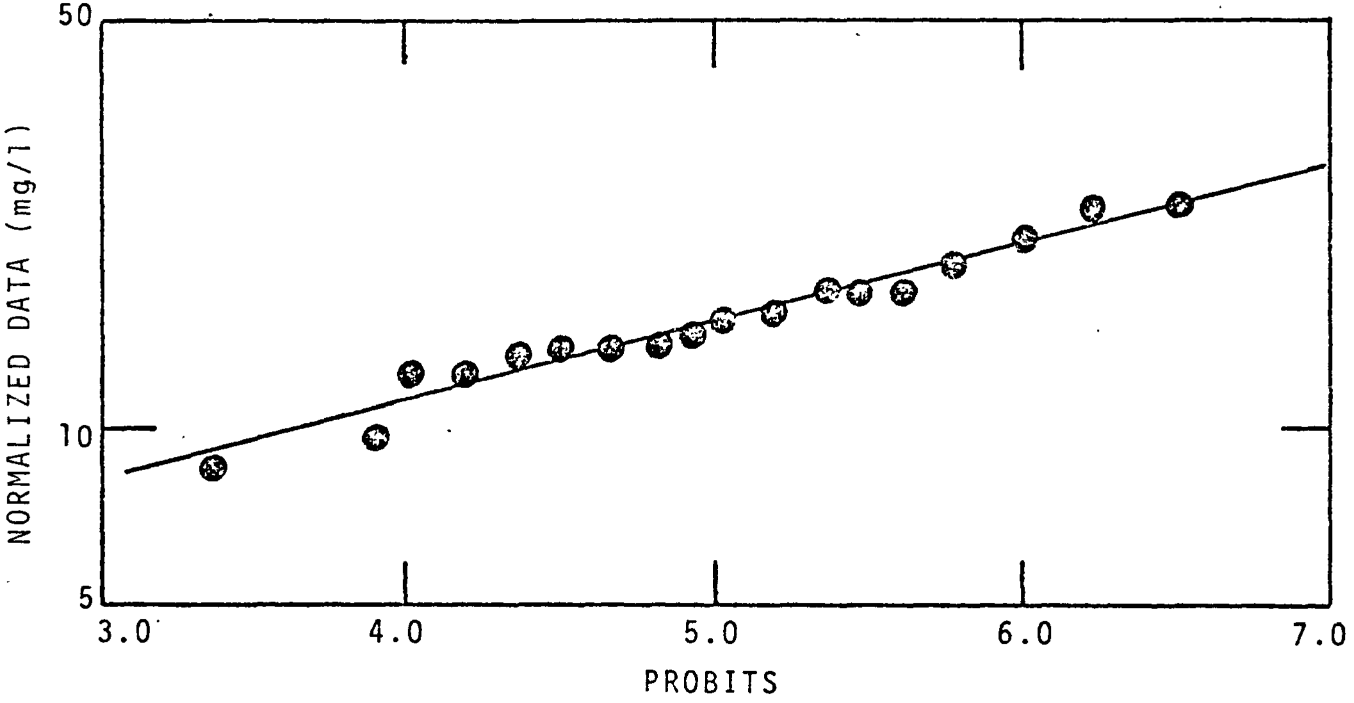

FIGURE A-5. Normal Distribution Diagram for Supsended Solids Concentration In Cooling Tower Blowdown (Plant 8696)

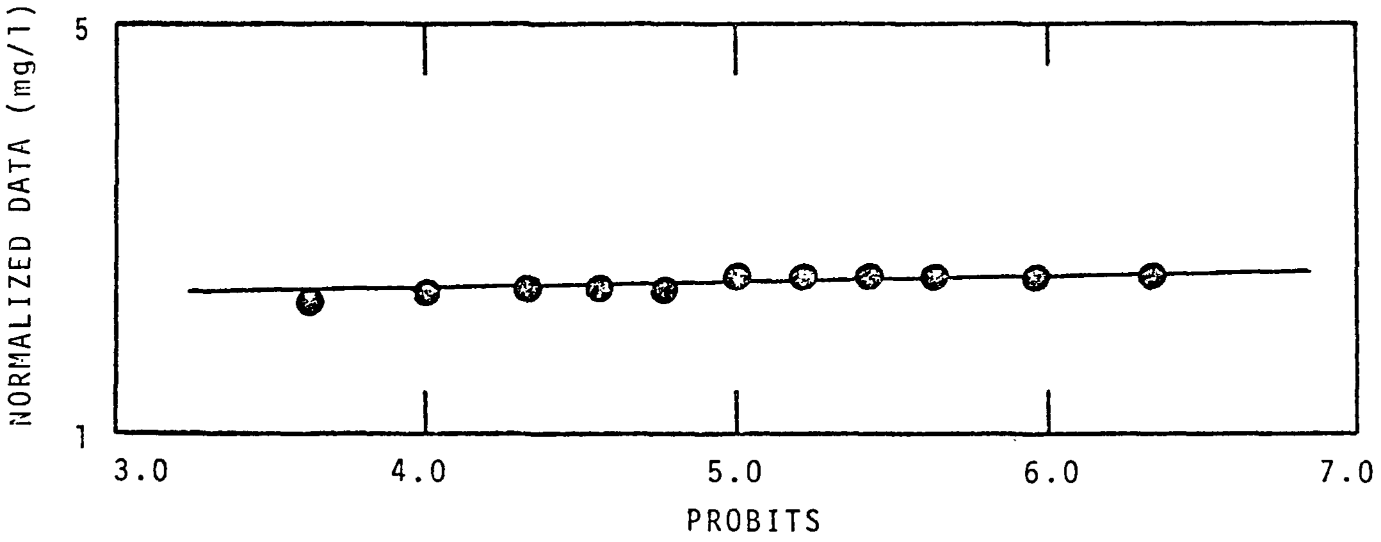

FIGURE A-6. Normal Distribution Diagram for COD Concentration In Cooling Tower Blowdown (Plant 8696)

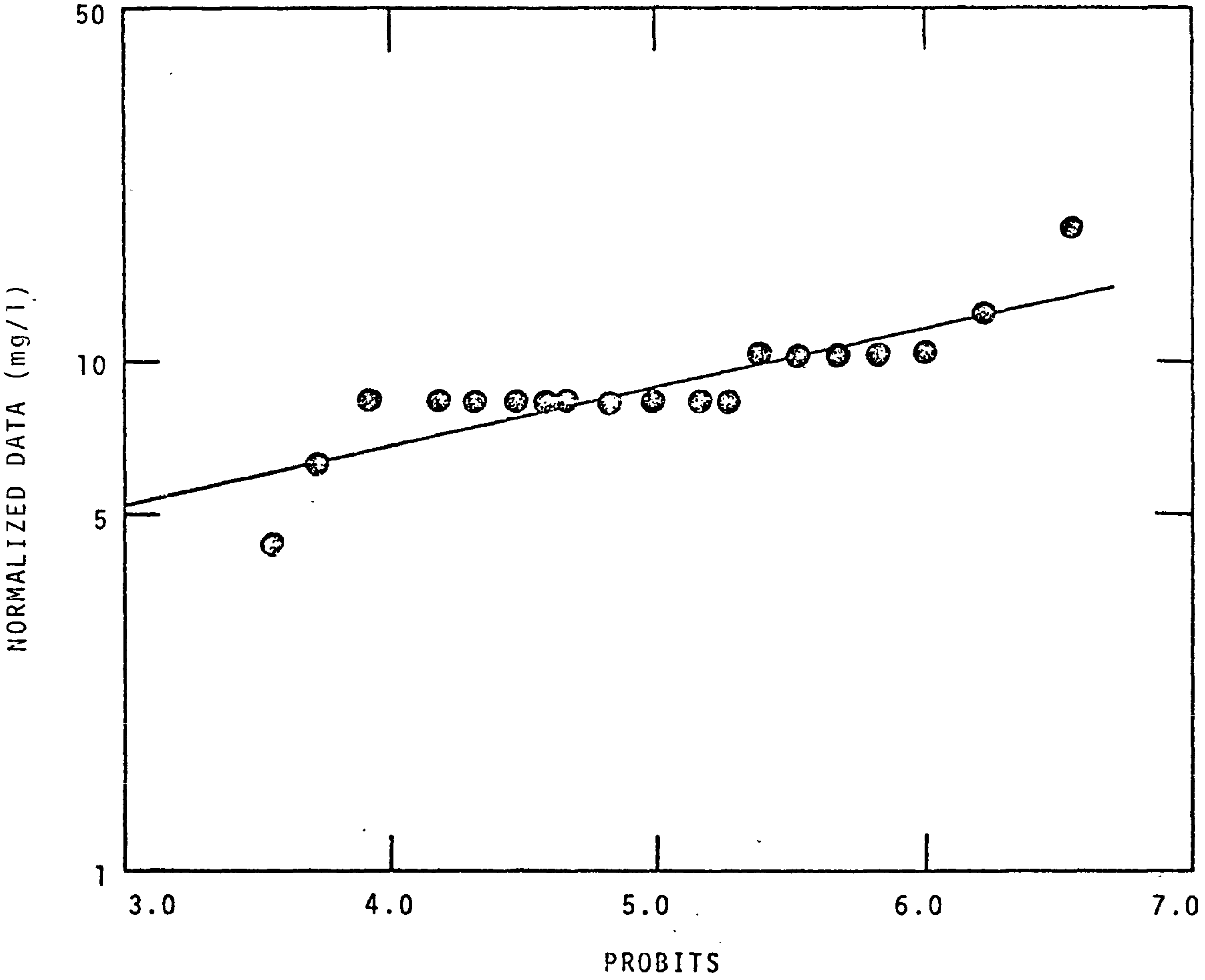

FIGURE A-7. Normal Distribution Diagram for Chromates Concentration In Cooling Tower Blowdown (Plant 8392)

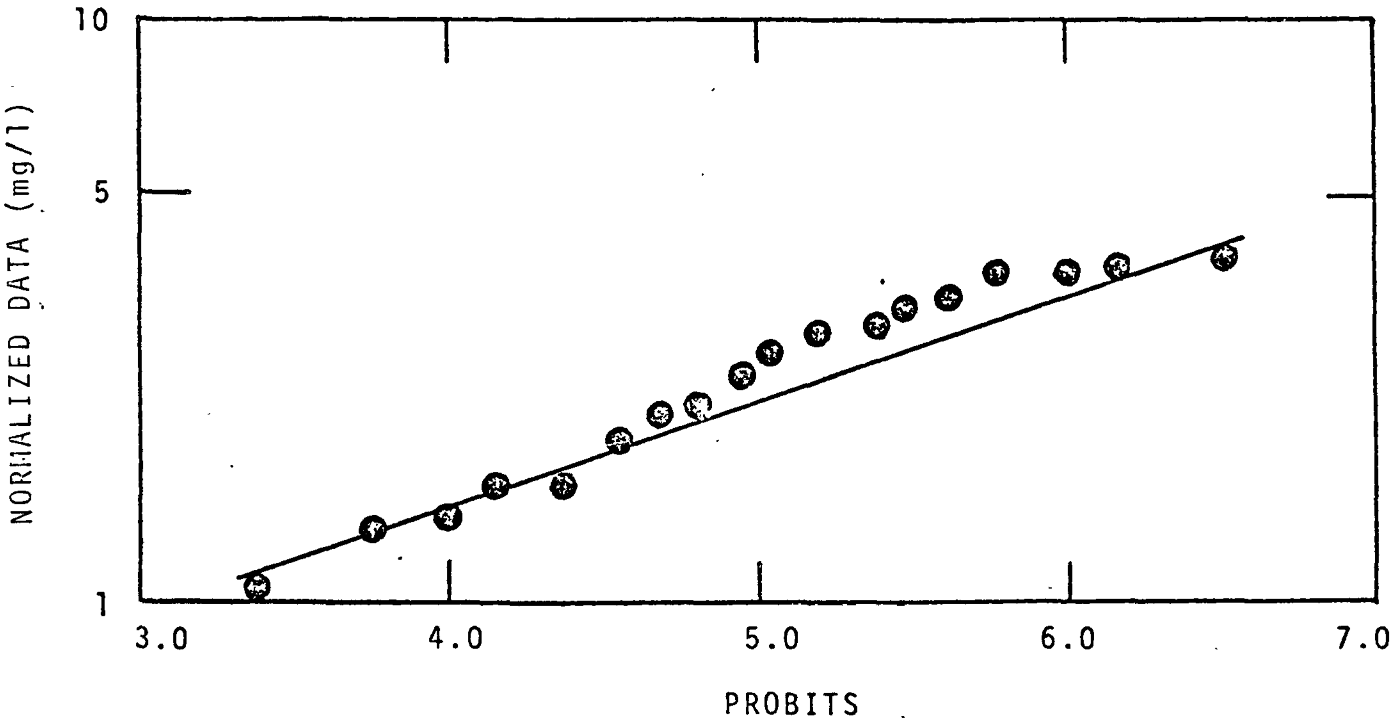

FIGURE A-8. Normal Distribution Diagram for BOD_5 Concentration In Cooling Tower Blowdown (Plant 8696)

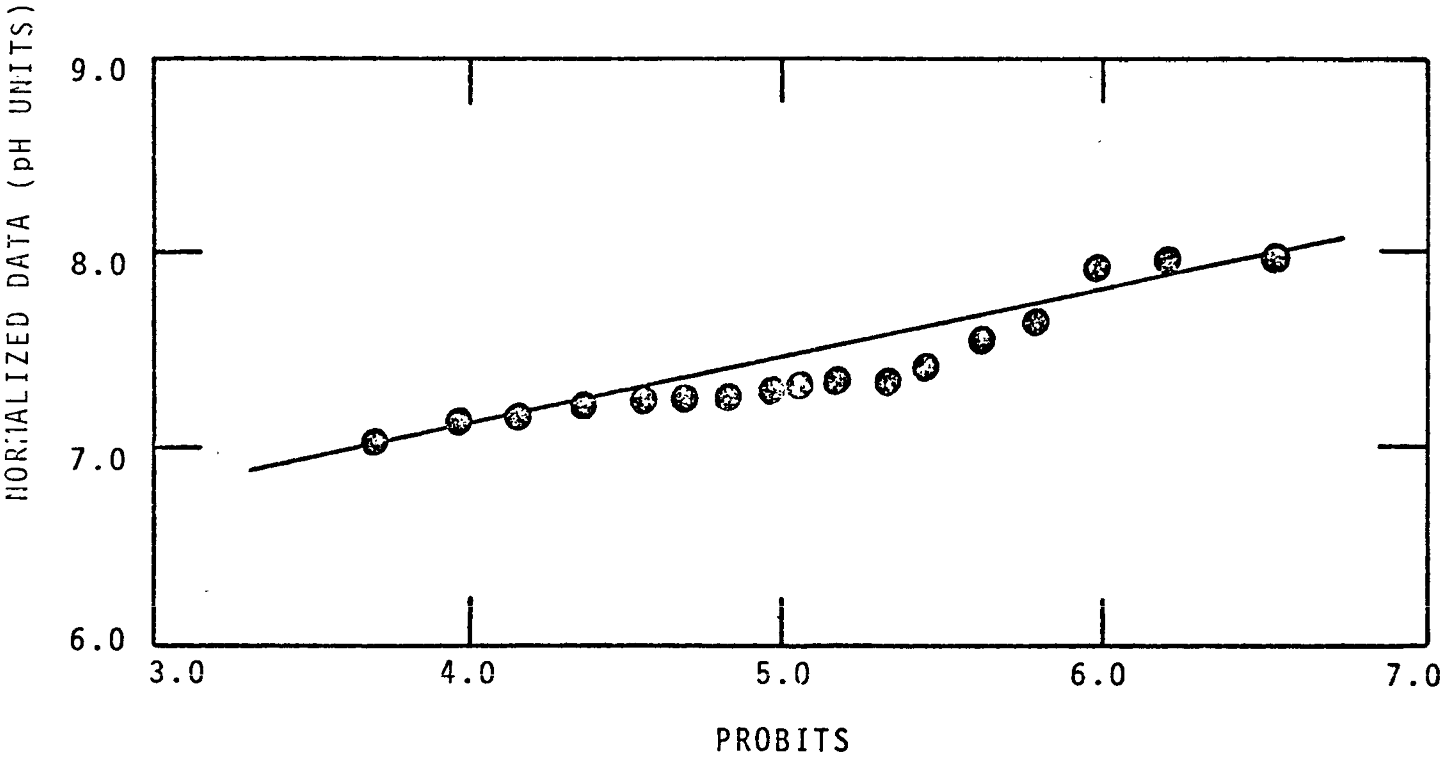

FIGURE A-9. Normal Distribution Diagram for pH Concentration In Cooling Tower Blowdown (Plant 8696)

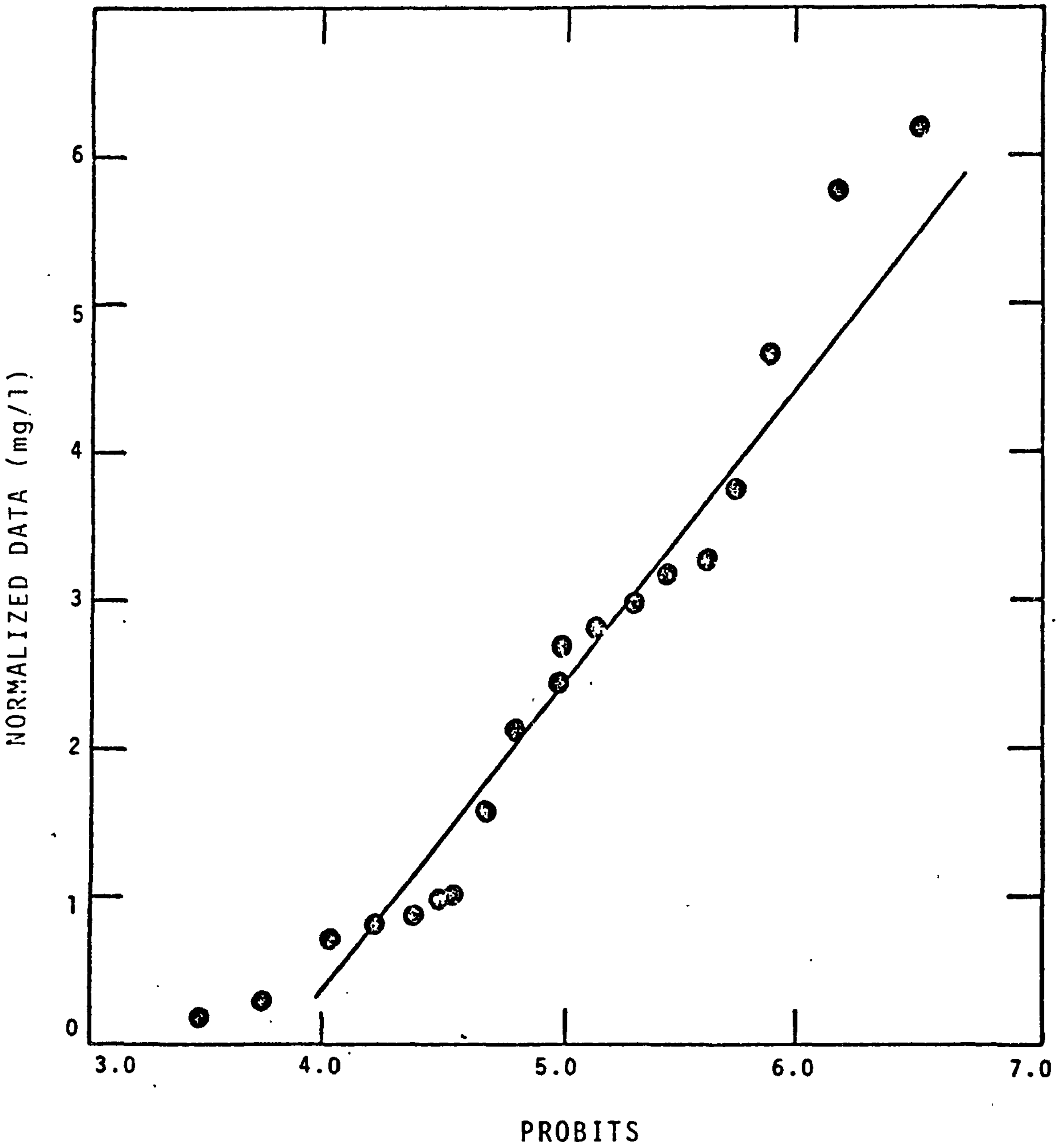

FIGURE A-10. Normal Distribution Diagram for BOD_5
Concentration in Demineralizer Backwash
(Plant 8696)

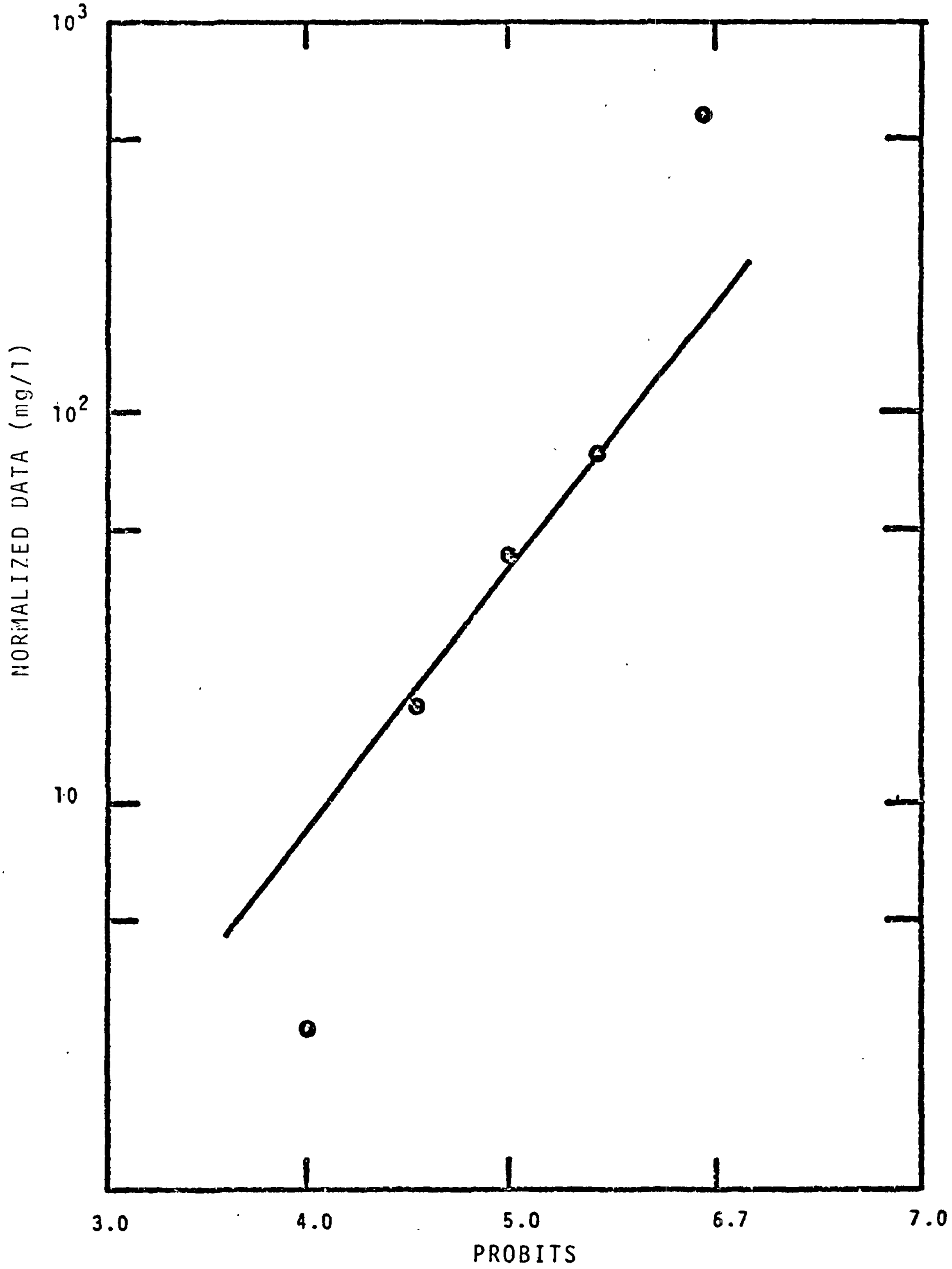

FIGURE A-11. Normal Distribution Diagram for Normalized Nickel Concentration in Retention Pond (Plant No. 7308)

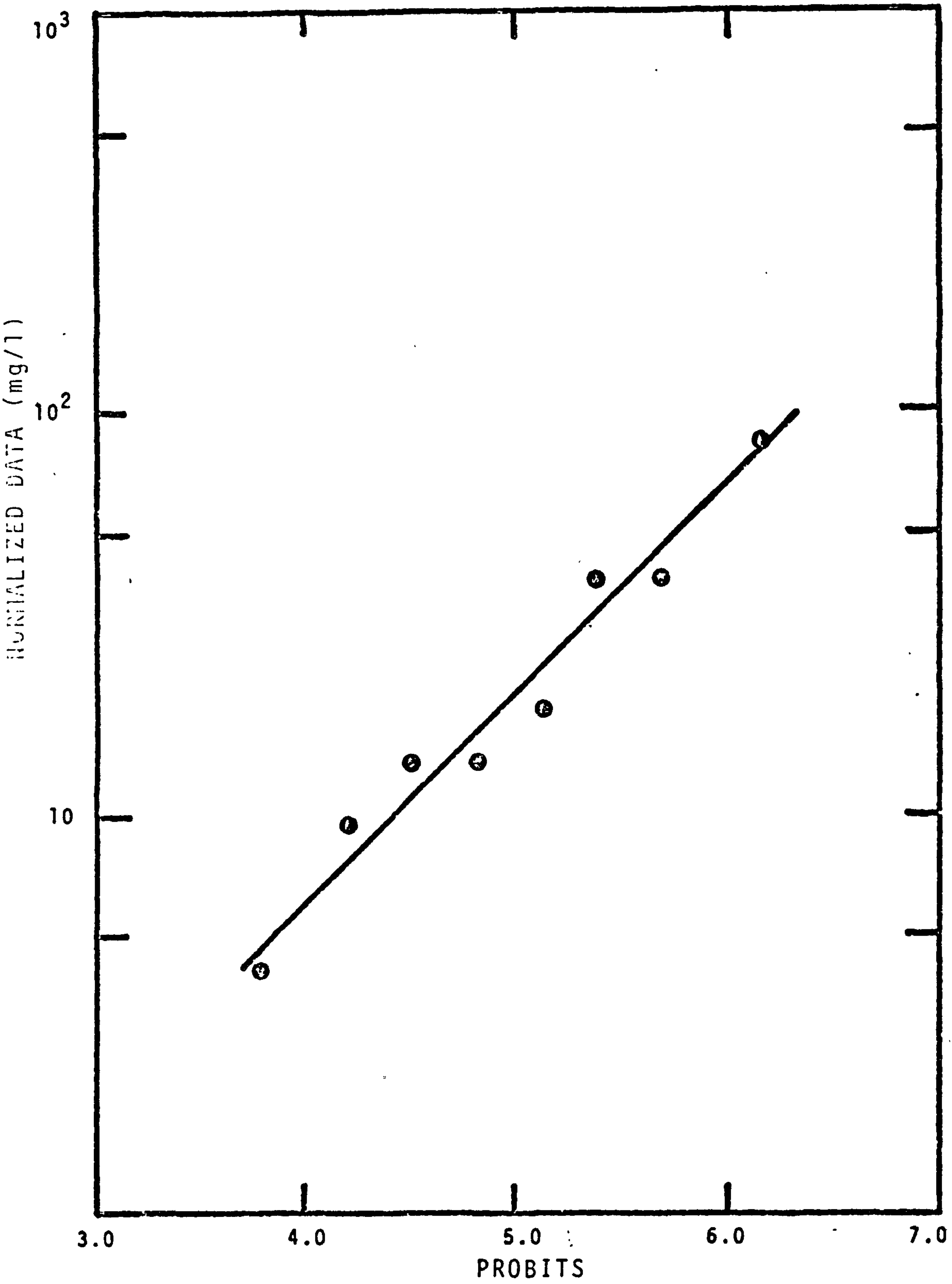

FIGURE A-12. Normal Distribution Diagram for Normalized Chromium Concentration in Cooling Tower Basin (Plant No. 7308)

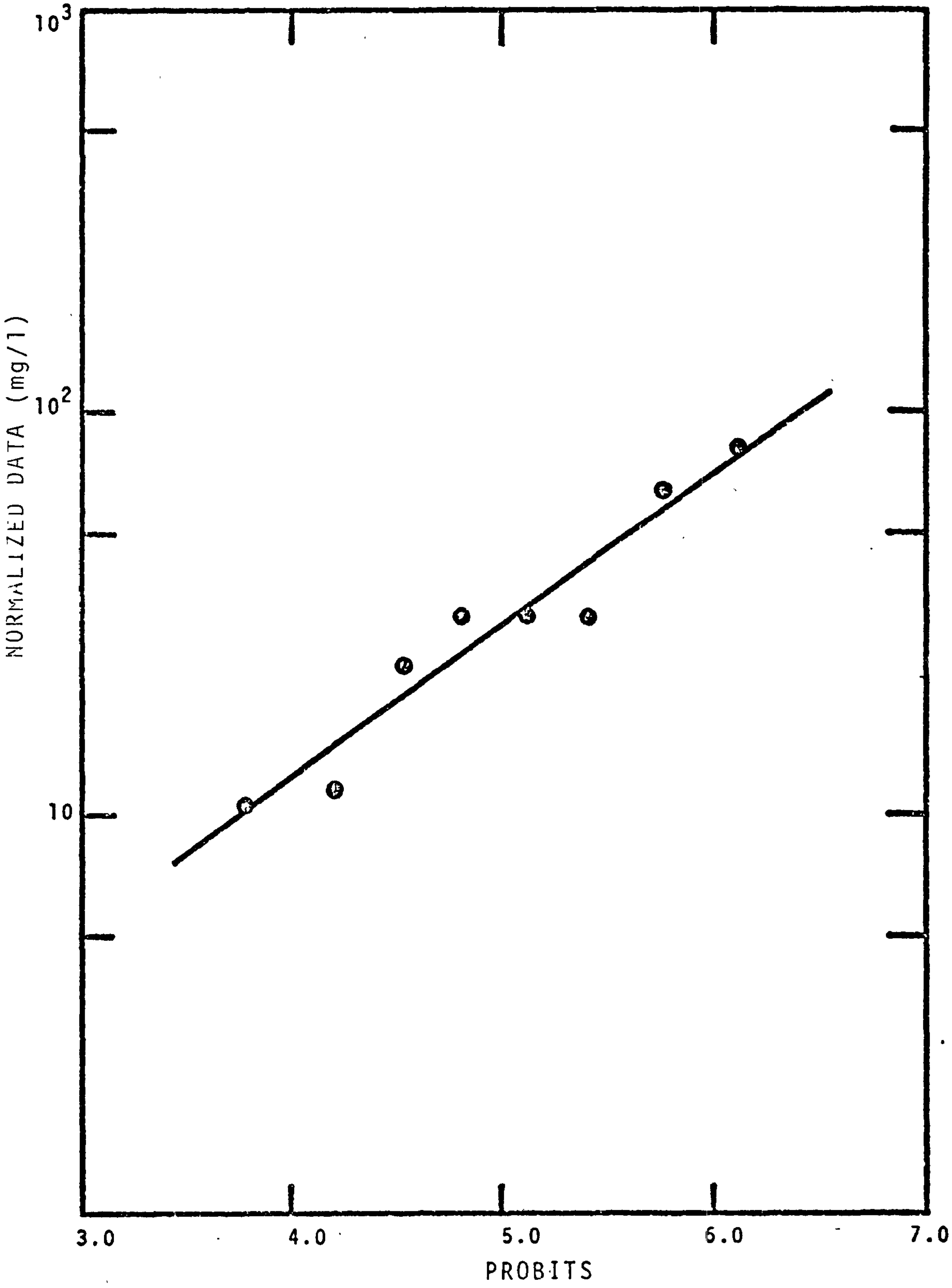

FIGURE A-13. Normal Distribution Diagram for Normalized Lead Concentration in Cooling Tower Basin (Plant No. 7308)

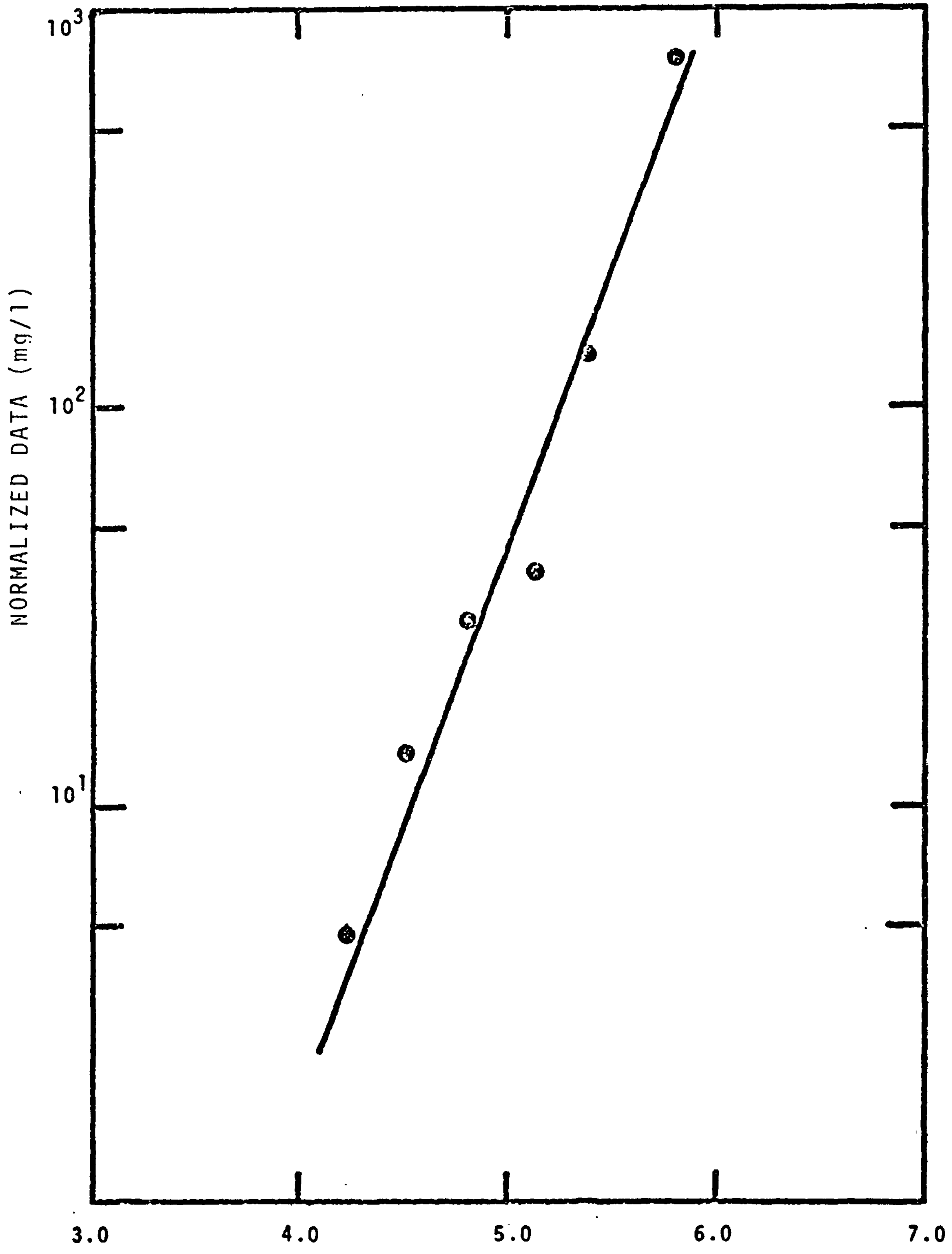

FIGURE A-14. Normal Distribution Diagram for Normalized Zinc Concentration In Cooling Tower Basin (Plant No. 7308)

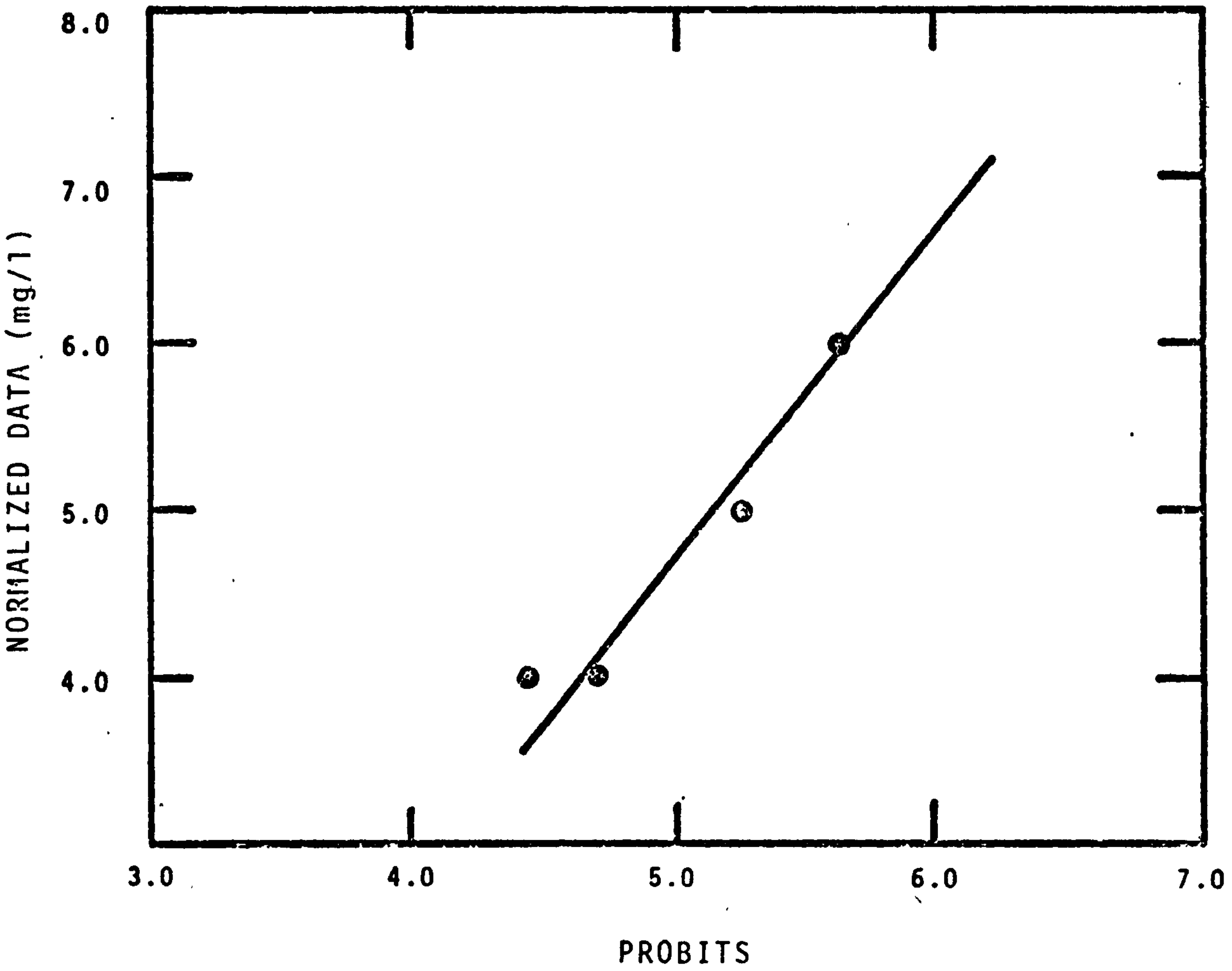

FIGURE A-15. Normal Distribution Diagram for Iron Concentration in Retention Pond (Plant No. 7308)

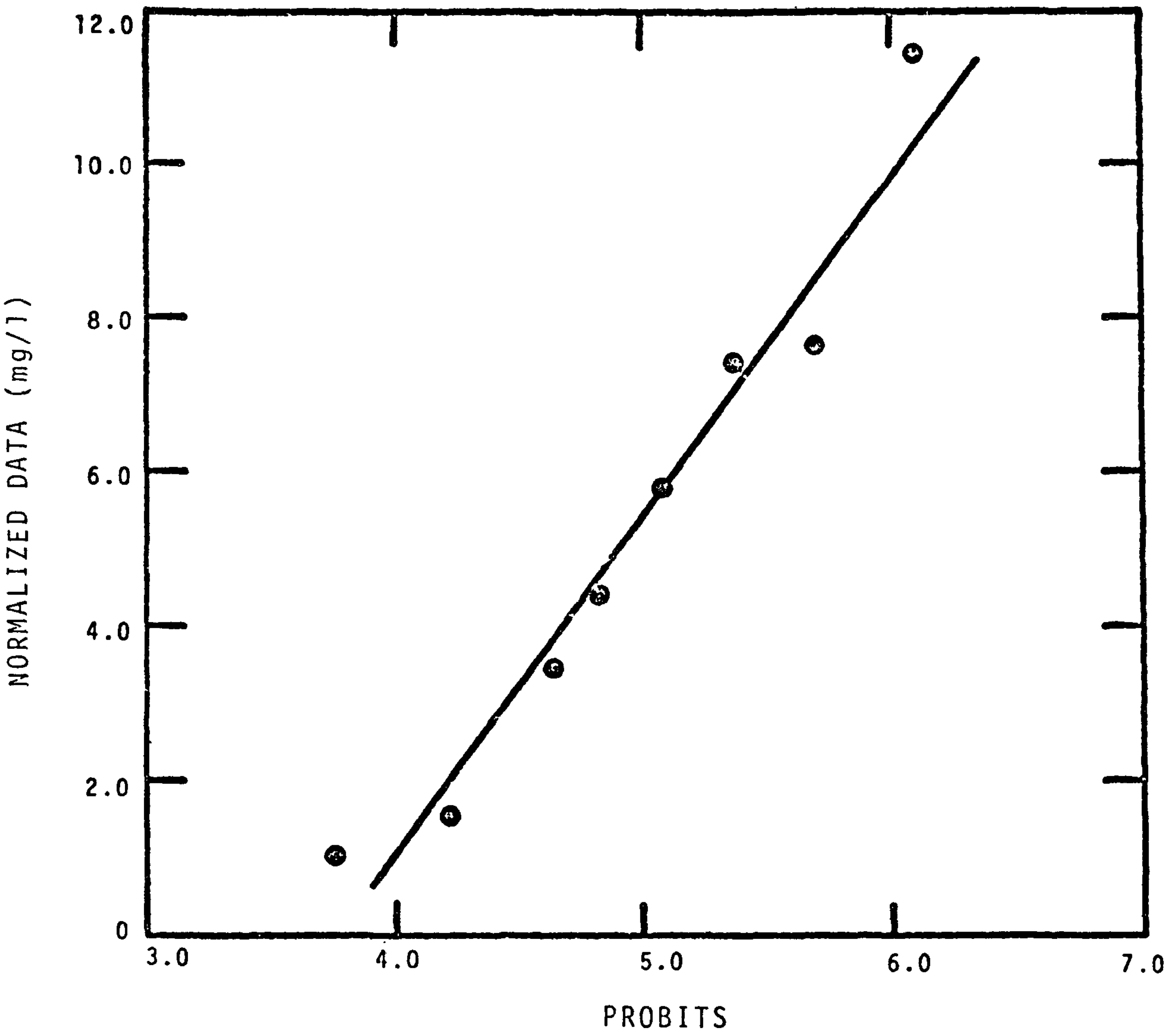

FIGURE A-16. Normal Distribution Diagram for Iron Concentration In Cooling Tower Basin (Plant No. 7308)

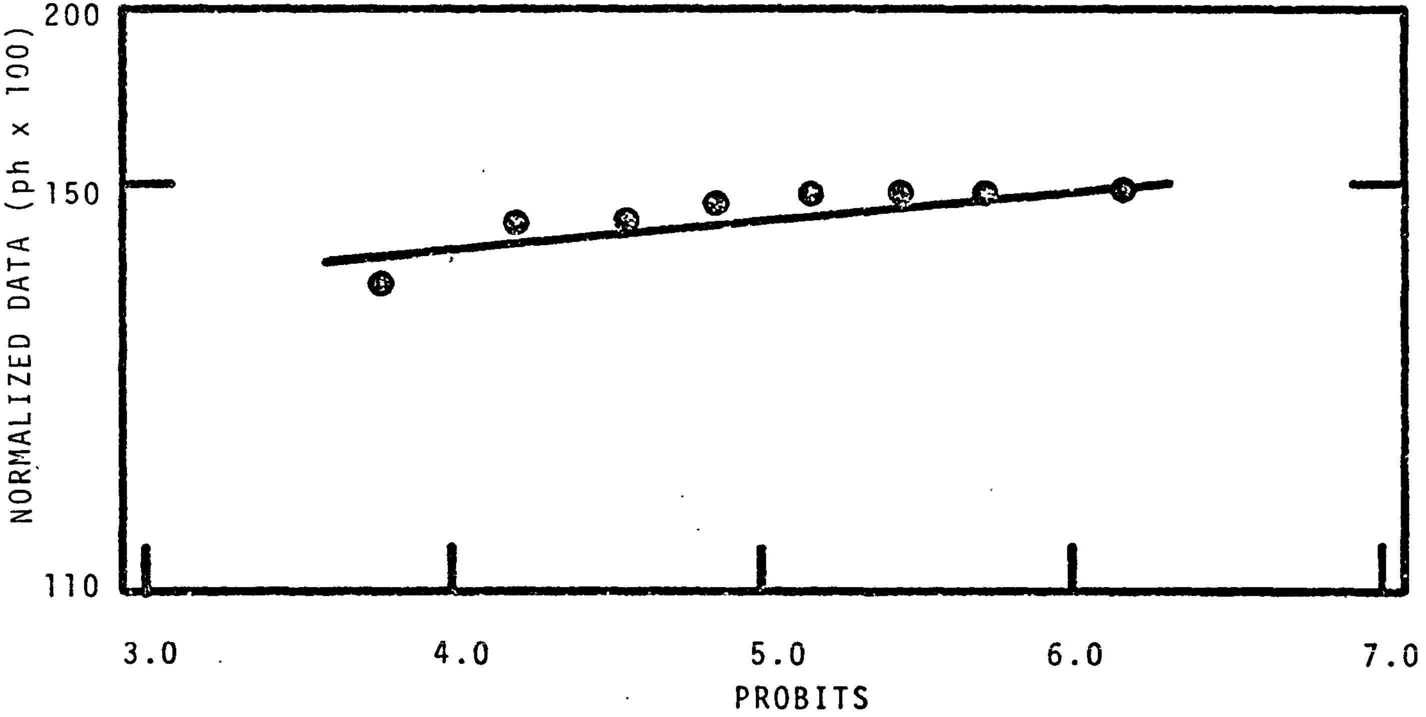

FIGURE A-17. Normal Distribution Diagram for Normalized pH Concentration In Cooling Tower Basin (Plant No. 7308)

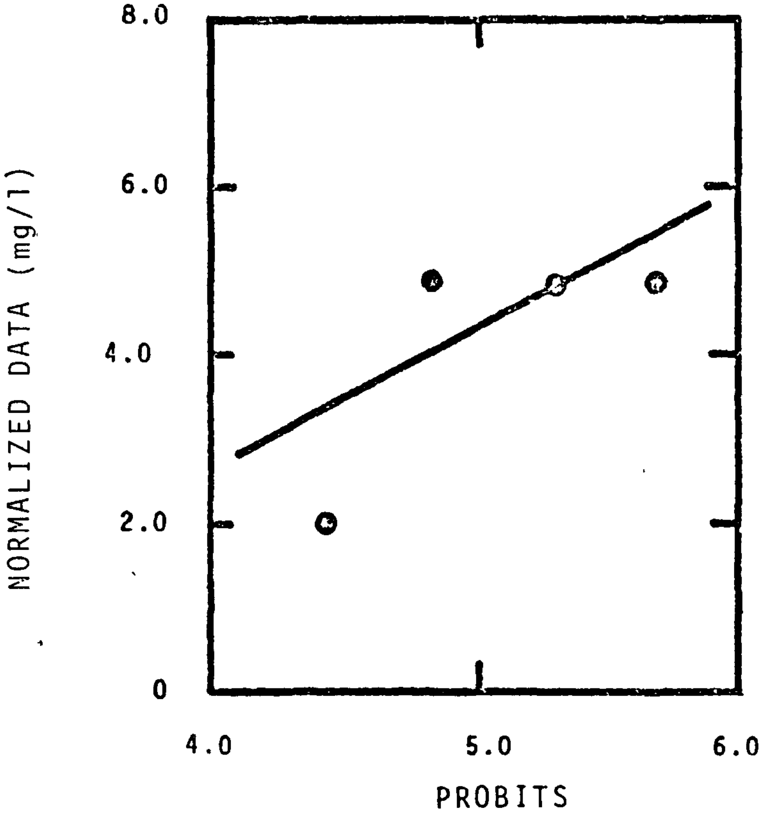

FIGURE A-18. Normal Distribution Diagram for Silver Concentration Retention Pond (Plant No. 7308)

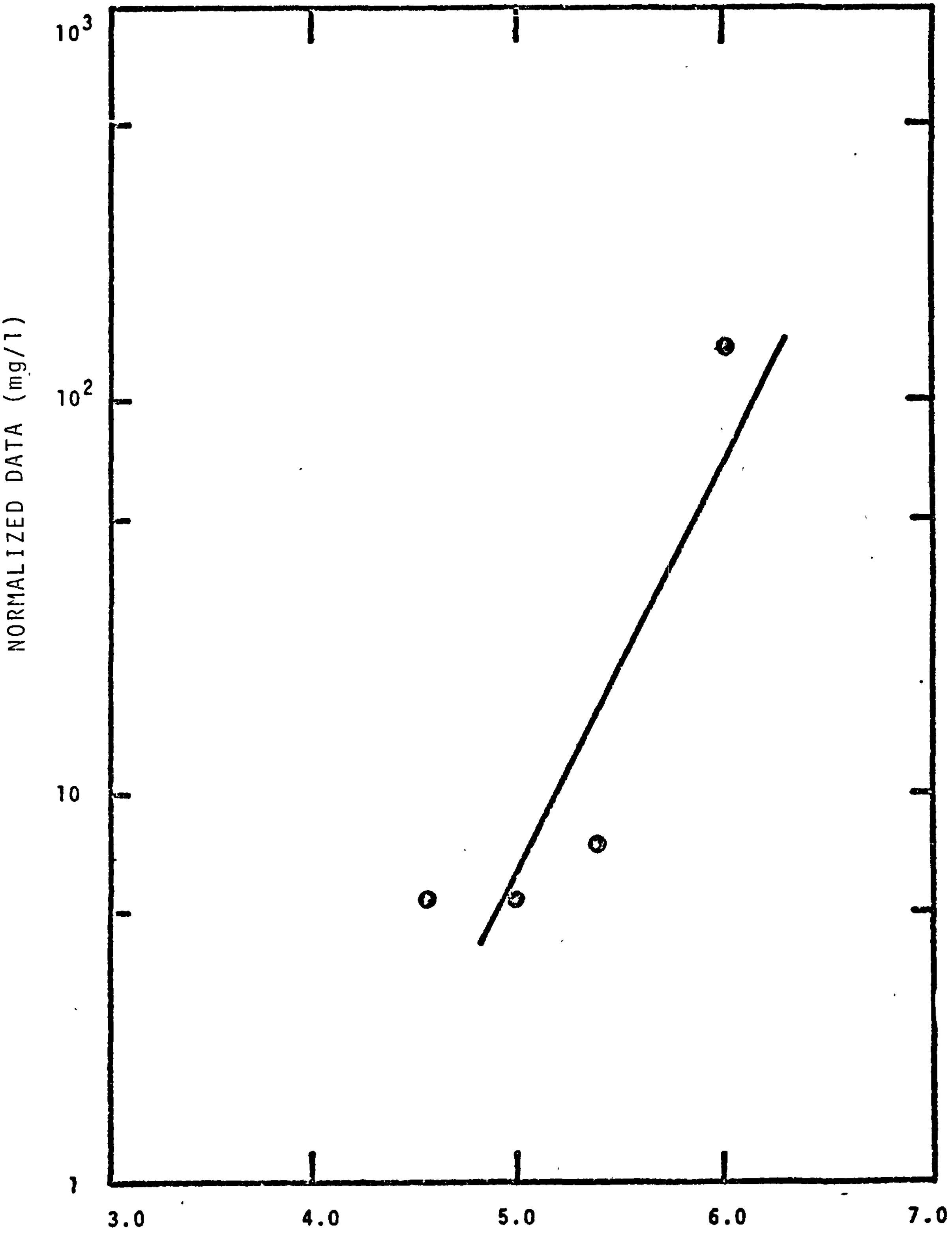

FIGURE A-19. Normal Distribution Diagram for Normalized Copper Concentration Cooling Tower Basin (Plant No.7308)

Table A-9. STATISTICAL ANALYSIS OF WATER USAGE DATA BY CATEGORY

Water Usage Category	Once-through Cooling Water x10^4			Recirculating Cooling Water			Boiler Makeup Water			Demineralizer Water		
Mode of Normal Distribution / Statistical Parameter	Arithmetic	Logarithmic (2)	Three Parameters Logarithmic (2)	Arithmetic	Logarithmic (2)	Three Parameters Logarithmic (2)	Arithmetic	Logarithmic (2)	Three Parameter Logarithmic (2)	Arithmetic	Logarithmic (2)	Three Parameter Logarithmic (2)
Mean	29.43	1.42	1.23	6.2	0.59	0.49	370	1.99	1.99	74.28	1.38	1.12
Variance	228.14	0.10	0.10	37.50	0.17	0.25	(1)	0.55	0.59	(1)	0.36	0.73
Third Moment	3681.88	0.00	0.00	231.89	0.03	0.00	(1)	0.05	0.00	(1)	0.20	0.00
Fourth Moment	(1)	0.00	0.00	3060 0	0.06	0.16	(1)	0.74	0.89	(1)	0.36	1.45
Coefficient of Skewness	1.05	0.33	0.00	1.01	0.41	0.00	2.2	0.12	0.00	1.95	0.94	0.00
Coefficient of Kurtosis	3.08	2.12	2.01	2.18	2.06	2.43	6.98	2.49	2.58	5.05	2.81	2.70
Correction Constant			-7.86			-0.51			-1.20			-4.31
Slope			2.66			4.07			8.04			10.97
Intercept			0.13			0.00			0.00			0.00
Coeff. of Determination			0.99			0.92			0.96			0.97
99% Confidence Limit			2.37			0.86			4.23			1.31

(1) Greater than 10^4

(2) Expressed as logarithms

Table A-10. STATISTICAL PARAMETERS OF REGRESSION ANALYSIS OF WATER USAGE AGAINST PRODUCTION RATE

Water Usage Category Statistical Parameter	Once-through Cooling Water	Recirculating Cooling Water	Boiler Makeup Water	Demineralizer Water
Slope	-0.13	0.06	-0.92	0.03
Intercept	6.14	3.08	7.1	1.52
Coefficient of Determination	0.11	0.00	0.47	0.00
Standard Error of Estimated Water Use on Production Rate	0.23	0.77	0.57	0.65
Standard Error of Intercept	0.17	2.09	1.45	1.76
Standard Error of Slope	0.94	0.37	0.26	0.31

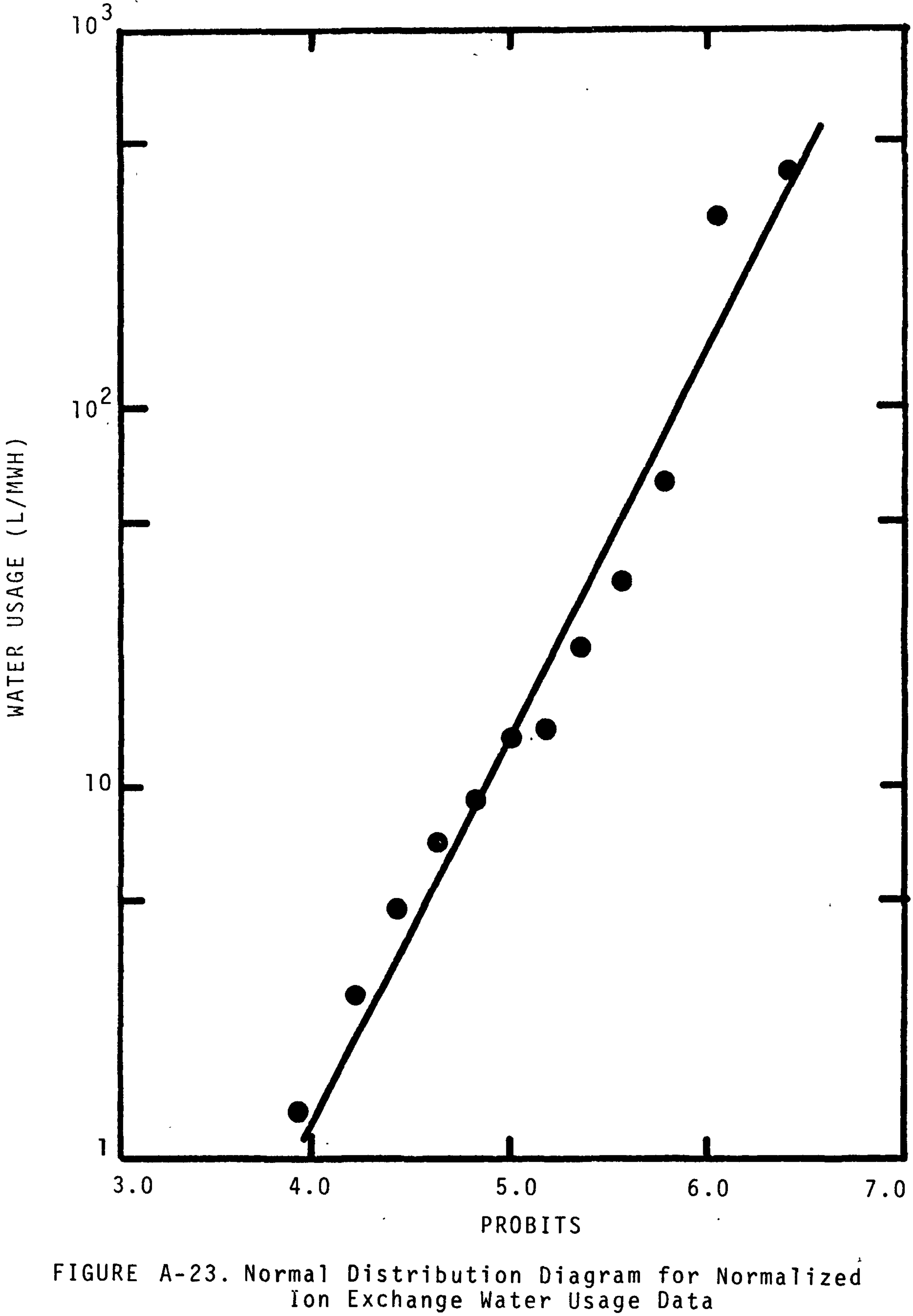

FIGURE A-23. Normal Distribution Diagram for Normalized Ion Exchange Water Usage Data

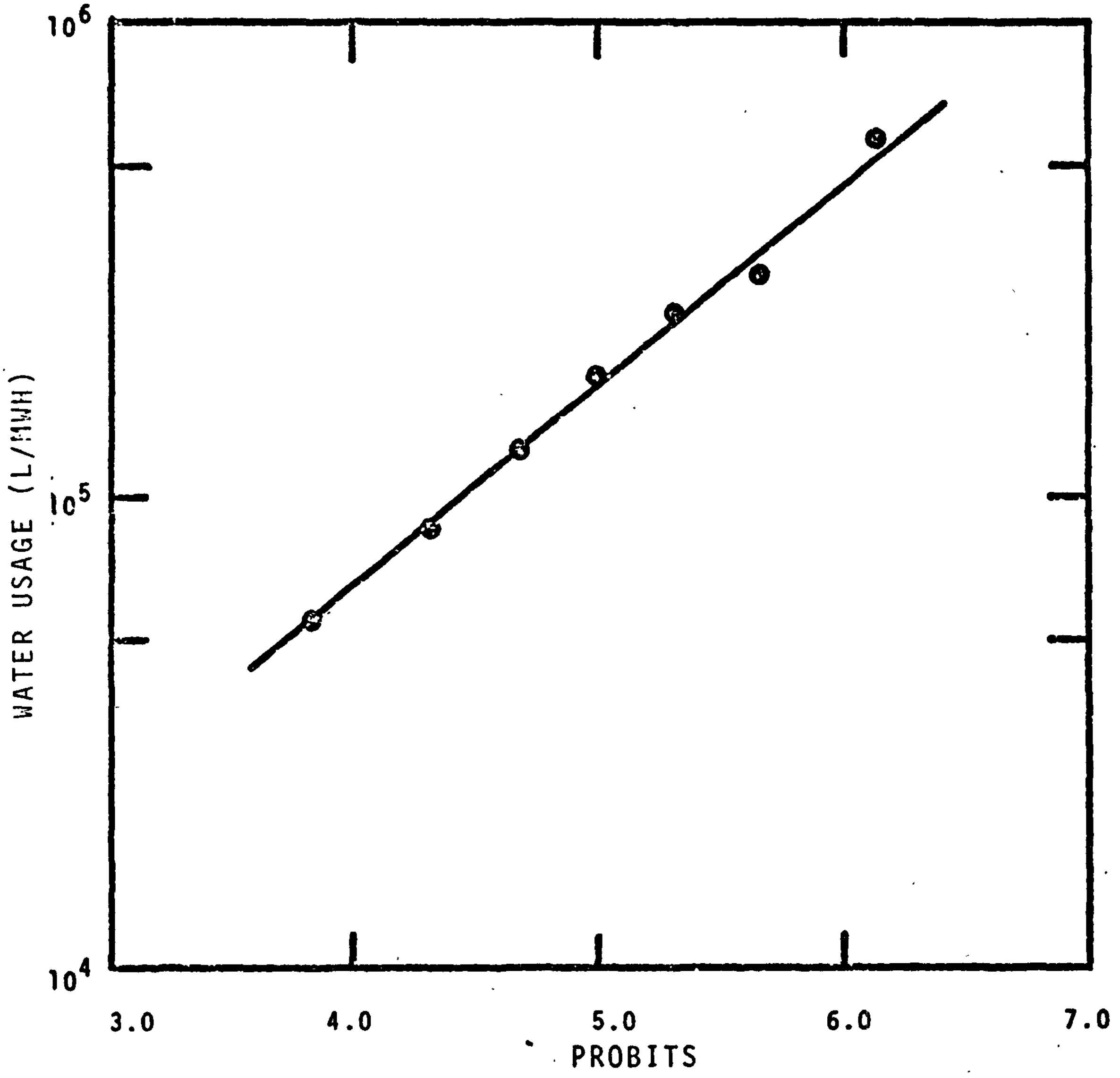

FIGURE A-20 . Normal Distribution Diagram for Normalized Once-Through Usage Data

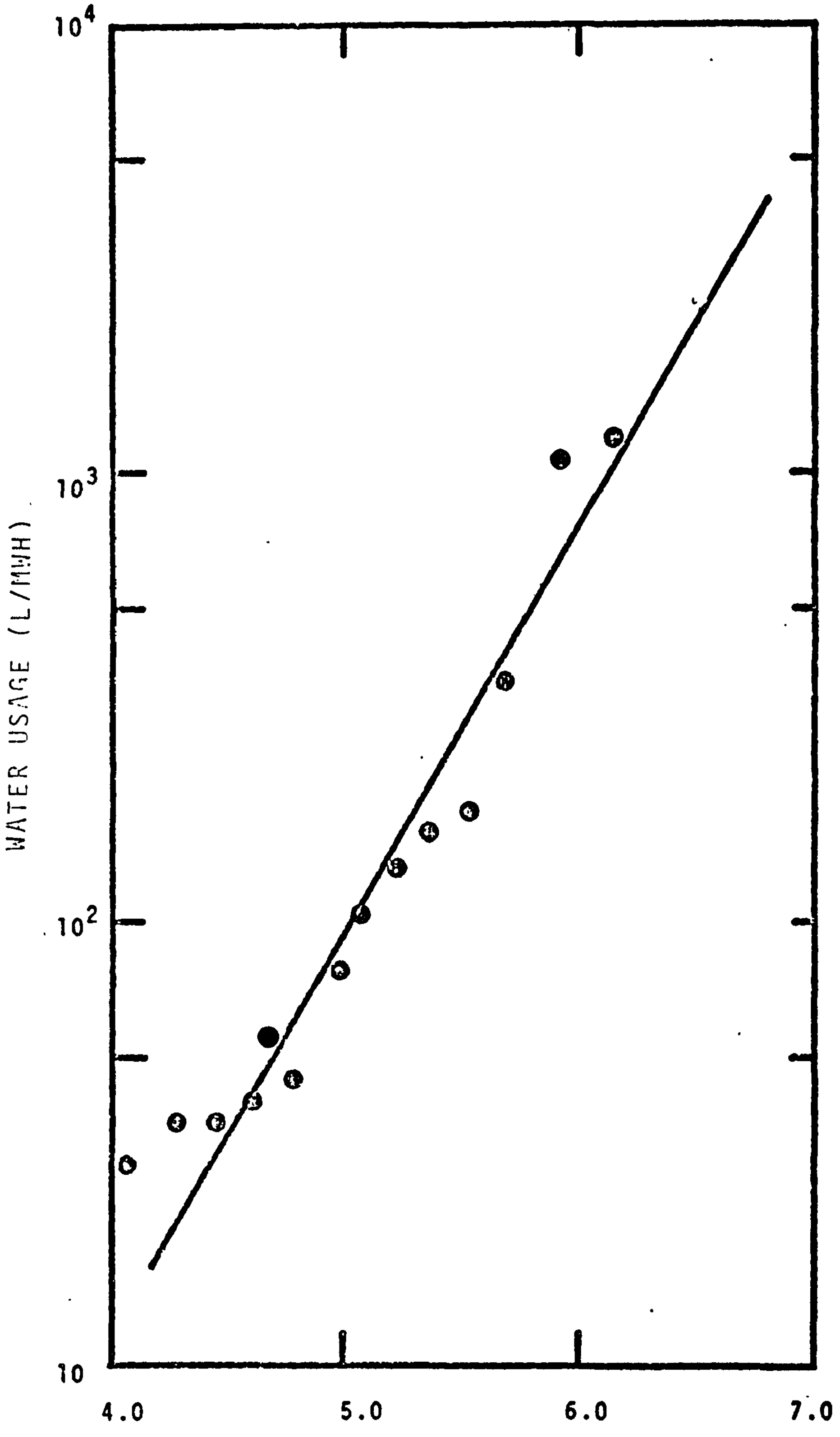

FIGURE A-22. Normal Distribution Diagram for Normalized Boiler Makeup Water Usage Data

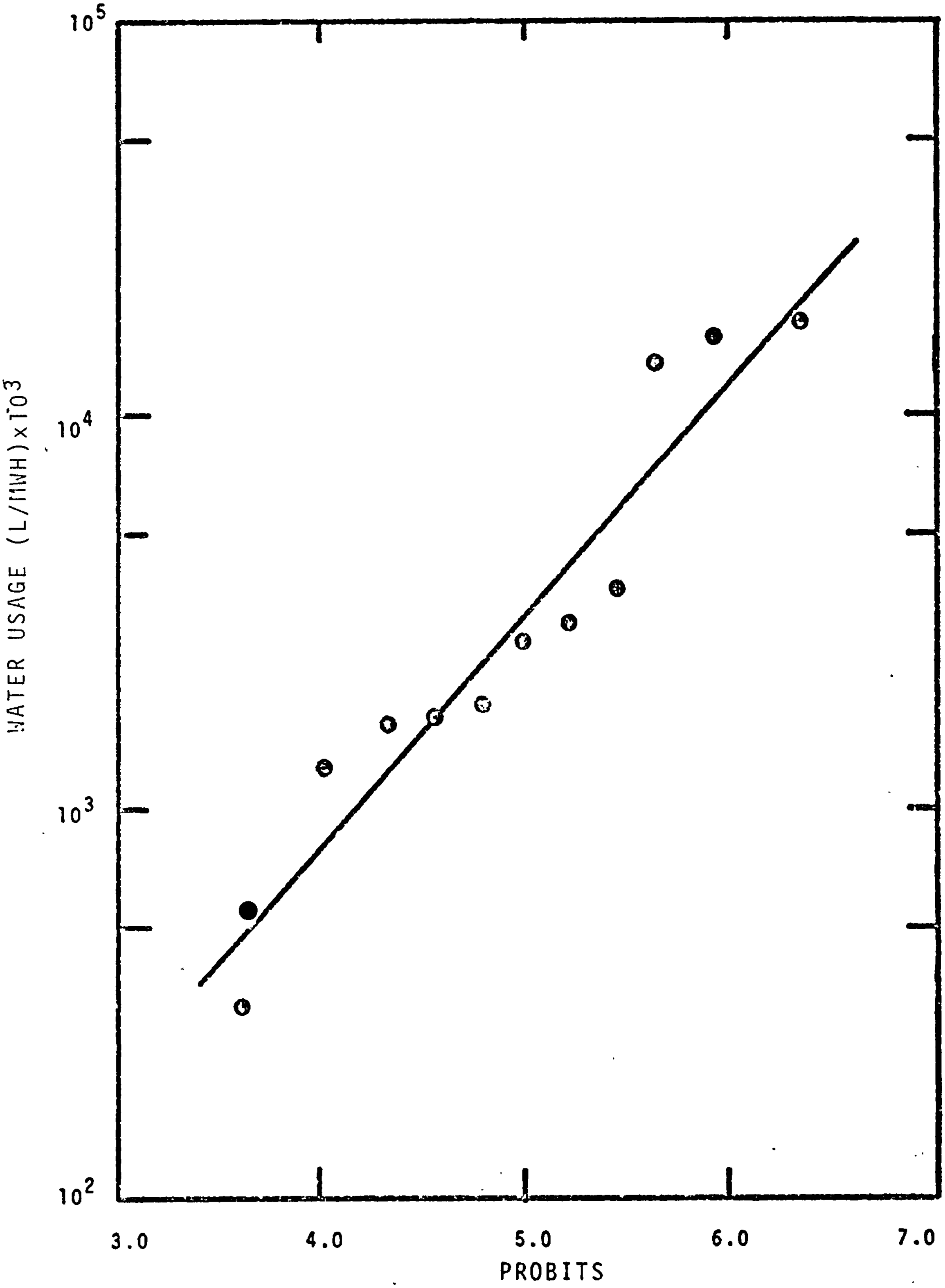

FIGURE A-21. Normal Distribution Diagram for Normalized Cooling Water Usage Data

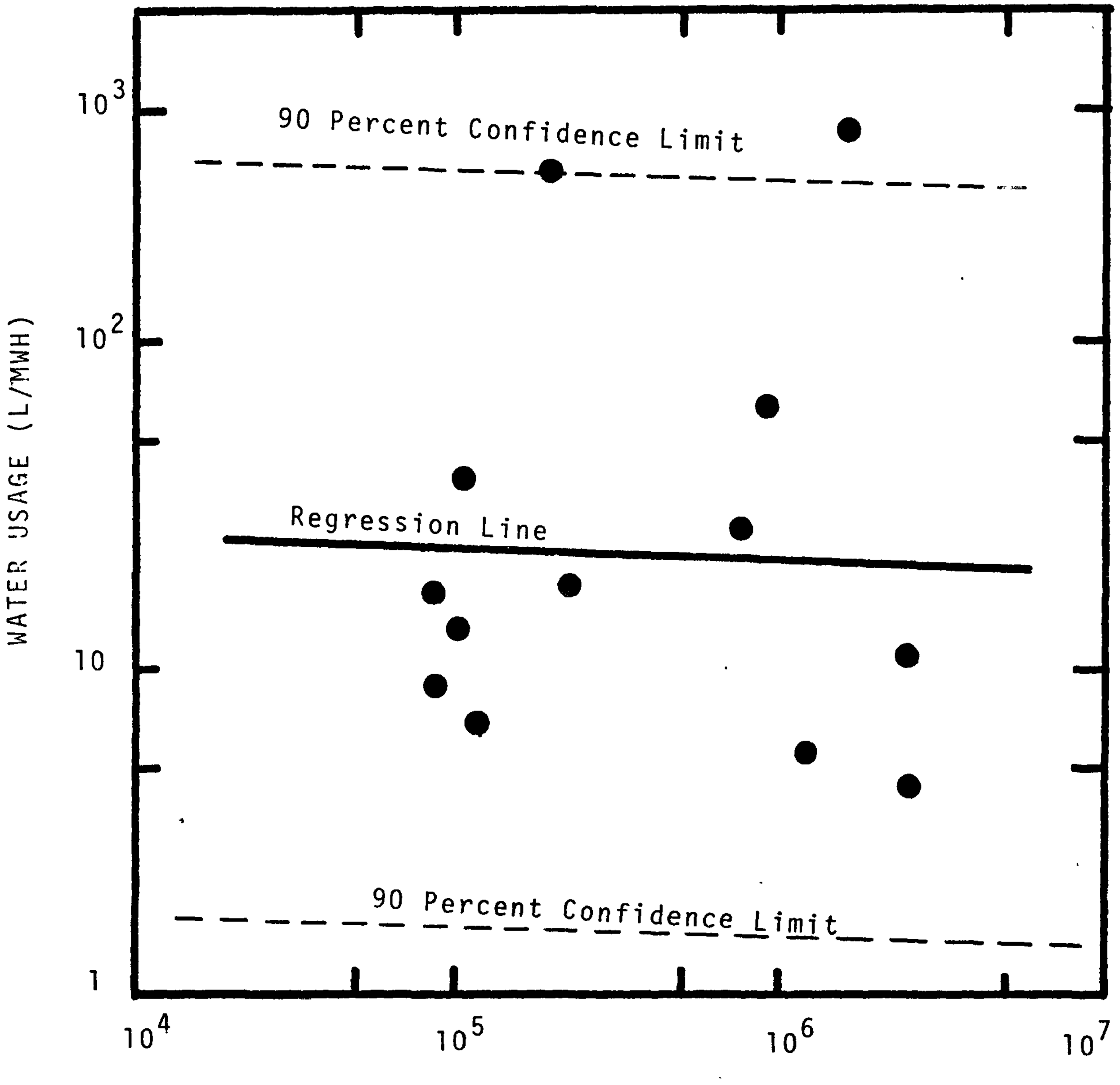

FIGURE A-27. Demineralizer Water Usage vs. Annual Production Rate

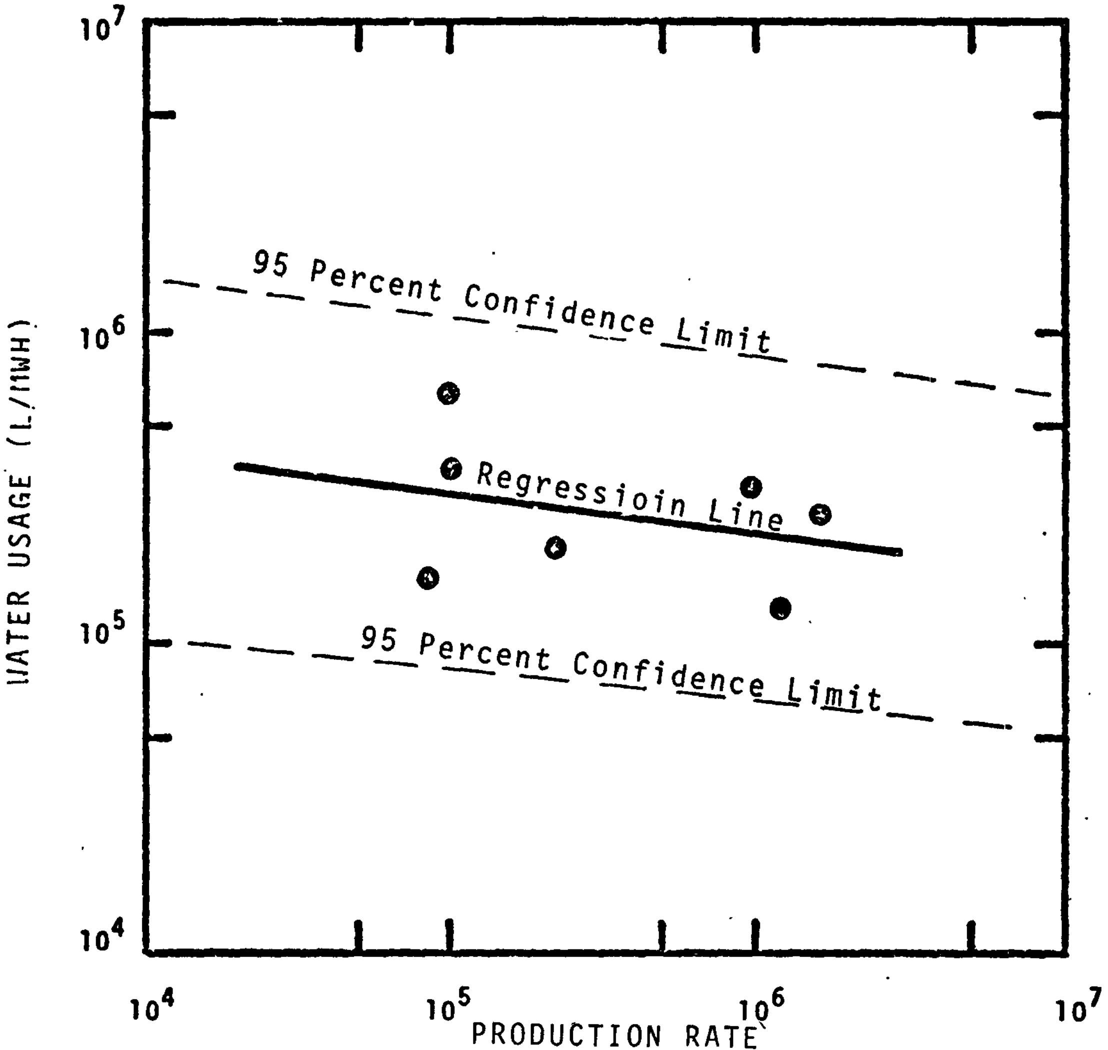

FIGURE A-24 . Once-Through Cooling Water Use vs. Annual Production Rate

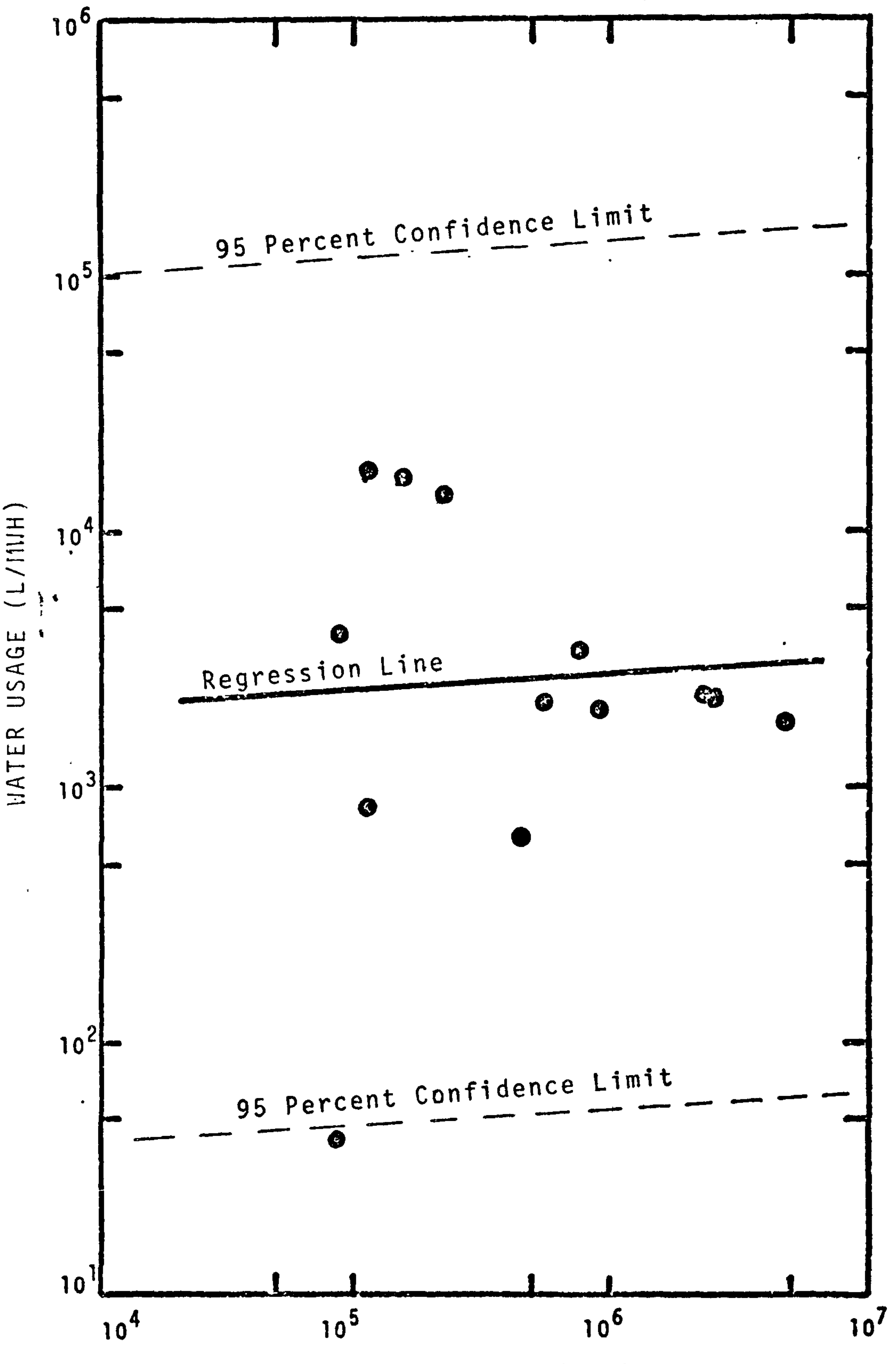

FIGURE A-25. Recirculating Cooling Water Use vs. Annual Production Rate

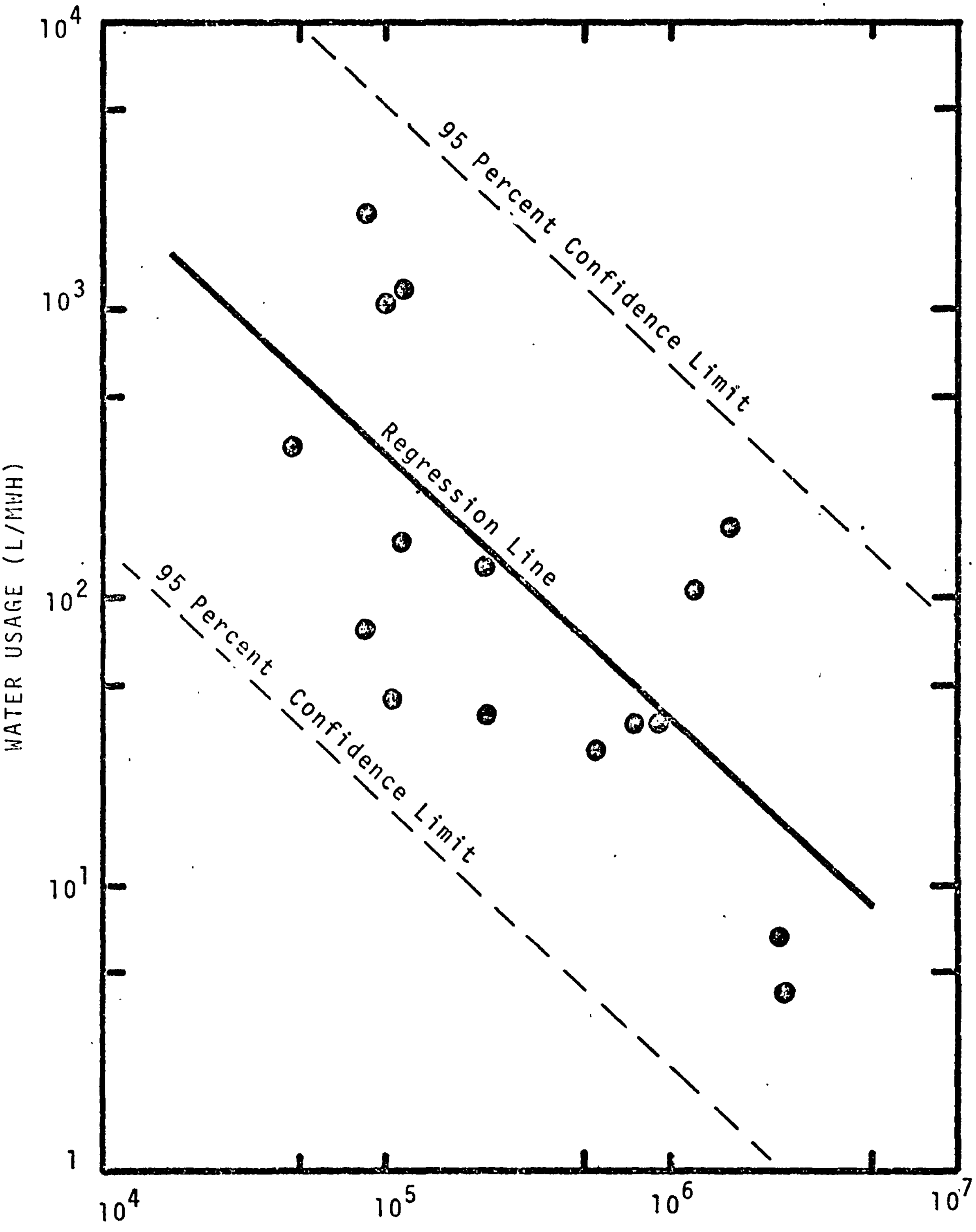

FIGURE A-26 Boiler Makeup Water Use vs. Annual Production Rate

APPENDIX B

WATER GLOSSARY

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. It is measured by titration with a standard solution of a base to a specified end point. Usually expressed as miligrams per liter of calcium carbonate.

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 ft deep, or 43,560 cu ft. (2) A term used in sewage treatment in measuring the volume of material in a trickling filter. One acre-foot contains 43,cu ft of water.

Activated Carbon - Carbon which is treated by high-temperature heating with steam or carbon dioxide producing an internal porous particle structure. The internal surface area of granular activated carbon is estimated to be about 3,600 sq ft gr.

Activiated Sludge Treatment Process - (See Sludge, Activated).

Adsorption - The adhesion of an extremely thin layer of molecules (of gas, liquid) to the surfaces of solids (granular activiated 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 that 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).

Aerobic - Living or active only in the presence of oxygen.

Aerobic Biological Oxidation - Any waste treatment or process utilizing aerobic organisms in the presence of air or oxygen, as the agent for reducing pollution load or oxygen demand or organic substances in waste. The term is used in reference to secondary treatment of wastes.

Algicide - Chemicals used in the control of phytoplankton (algae) in bodies of water.

Alkalinity - The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occassionally borates, silicates, and phosphates. It is expressed in miligrams per liter of equivalent calcium carbonate.

Anaerobic - Living or active only in the absence of free oxygen.

Anaerobic Biological Treatment - Any treatment method or process utilizing anaerobic or facultative organisms in the absence of air for the purpose of reducing the organic matter in wastes or organic solids settled out of wastes commonly referred to as anaerobic digestion or sludge digestion when applied to the treatment of sludge solids.

Anaerobic Waste Treatment - Waste stabilization brought about through the action of microorganisms in the absence of air or elemental oxygen. Usually refers to waste treatment by methane fermentation.

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 substances that has been widely used in cleaning products.

The hydrophilic group of these surfactants carries a negative charge in washing solution.

Apparent Density (Activated Carbon) - The weight per unit volume of activated carbon.

Appurtenances, Sewer - Structures, devices and appliances, other than pipe or conduit, which are integral parts of a sewerage system: such as manholes flush tanks, surface inlets.

Aquifer - A subsurface geological structure that contains water.

Assimilative Capacity - The capacity of a natural body of water to receive: (a) wastewaters without deleterious effects: (b) toxic materials, without damage to aquatic life or humans who consume the water; (c) BOD within prescribed dissolved oxygen limits.

Autooxidation - A chemical system which will oxidize automatically when some set of conditions are met such as temperature, oxygen supply, moisture content, etc.

Backflow Prevention - A system designed to protect potable water from wastewater contamination which could occur if wastewater pressure exceeds potable water pressure over a cross-connection where one or more check valves fail.

Backsiphonage - The flowing back of contaminated or polluted water from a plumbing fixture or cross connection into a water supply line, due to a lowering of the pressure in such line.

Backwashing - The process of cleaning a rapid sand or mechanical filter by reversing the flow of water.

Bacterial Examination - The examination of water and wastewater to determine the presence, number, and identification of bacteria. Also called bacterial analysis.

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.

Banks, Sludge - Accumulations on the bed of a waterway of deposits of solids of sewage or industrial waste origin.

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 - (1) An assay method using a change in biological activity as a qualitative or quantitative means of analyzing a materials reponse 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 biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions (2) standard test used in assessing wastewater strength.

Biocides - Chemical agents with the capacity to kill biological life forms. Bactericides, insecticides, pesticides, etc. are examples.

Biodegradable - This part of organic matter which can be oxidized by bioprocesses, e.g., biodegradable detergents, food wastes, animal manure, etc.

Biological Wastewater Treatment - Forms of wastewater treatment in which bacterial or biochemical action is intensified to stablize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filters, contact beds, trickling filters, and activated sludge process are examples.

Blowoff - A controlled outlet on a pipeline, tank, or conduit which is used to discharge water or accumulations of material carried by the water.

Branch - (1) A special form of vitrified sewer tile and cast iron pipe used for making connections to a sewer or water main. They are called T, Y, T-Y, double Y, and V branches according to their respective shapes. (2) Any part of a piping system other than a main.

Broad-Crested Weir - A weir having a substantial width of crest in the direction parallel to the direction of flow of water over it. This type of weir supports the nappe for an appreciable length and produces no bottom contraction of the nappe. Also called widecrested weir.

Buffer - Any of certain combinations of chemicals used to stablize the pH values or alkalinities of solutions.

Bulking Agent - A fine solid material which is sometimes added to a wastewater stream to produce clarification or coagulation by adding bulk to the solids.

Bulking, Sludge - A phenomenon that occurs in activated sludge plants whereby the sludge occupies excessive volumes and will not concentrate readily.

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 giving quantitative measurements.

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.

Carbon Tetrachloride Activity - The maximum percentage increase in weight of a bed of activated carbon after air saturated with carbon tetrachloride is passed through it at a given temperature.

Catalyst - A substance which accelerates or retards a chemical reaction without undergoing any permanent changes.

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 group is positively charged; usually a quaternary ammonium salt such as cetyl trimethyl ammonium bromide (CeTAB), $C_{16}H_{33}N + (CH_3)_3$ Br Cationic surfactant as a class are poor cleaners, but exhibit remarkable disinfectant properties.

Cesspool - An underground pit into which raw household sewage or other untreated liquid waste is discharged and from which the liquid seeps into the surrounding soil or is otherwise removed. Sometimes called leaching cesspool.

Chamber Detritus - A detention chamber larger than a grit chamber usually with provision for moving sediment without interrupting the flow of liquid. A settling tank of short detention period designed, primarily to remove heavy settleable solids.

Chamber, Flowing-Through - The upper compartment of a two-story sedimentation tank.

Chamber, Grit - A small detention chamber or an enlargement of a sewer designed to reduce the velocity of flow of the liquid, to permit the separation of mineral from organic solids by differential sedimentation.

Chelating Agents - A chelating agent can attach 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 procedures 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) - (1) A test based on the fact that all organic compounds, with few exceptions can be oxidized to carbon dioxide and water by the action of strong oxidizing agents under acid conditions. Organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances. One of the chief limitations is its ability to differentiate between biologically oxidizable and biologically inert organic matter. The major advantage of this test is the short time required for evaluation (2 hr). (2) The amount of oxygen required for the chemical oxidation of organics in a liquid.

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.

Chlorite, 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.

Cipolletti Weir - A contract weir of trapezoidal shape, in which the sides of the notch are given a slope of one horizontal to four vertical to compensate as much as possible for the effect of end contractions.

Clarifier - A sedimentation tank.

Clear Well - A reservoir containing water which has been previously filtered or purified before goining into the standpipes or distribution system.

Coils, digester - A system of pipes for hot water or steam installed in a sludge digestion tank for the purpose of heating the sludge being treated.

Collection Systems - Piping and/or channel systems for gathering storm, domestic or industrial wastewaters. Can be combined or separate.

Collector, Grit - A device placed in a grit chamber to convey deposited grit to one end of the chamber for removal.

Collector, Sludge - A mechanical device for scraping the sludge on the bottom of a settling tank to a sump pump, from which it can be drawn by hydrostatic or mechanical action.

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.

Color - A measure of water quality, made by eye or with proper instrumentation.

Color Bodies - Those complex molecules which impart color (usually undesirable) to a solution.

Comminution - The process of cutting and screening solids contained in wastewater flow before it enters the flow pumps or other units in the treatment plant.

Compatable Pollutant - A specific substance in a waste stream which alone can create a potential pollution problem, yet is used to the advantage of a certain treatment process when combined with other waste streams.

Complexing - The use of chelating or sequestering agents to form relatively loose chemical bonding as a means of treating certain pollutant such as nickel, copper, and cobalt.

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 sample. 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 receiprocal of the hydrogen ion concentration.

Conductance - A measure of the conducting power of a solution equal to the reciprical of the resistance. The resistance is expressed in ohms.

Contact Coagulation - A water clarification process which involves the addition of a coagulant with appropriate mixing for the purpose of floc formation within a filter media, which will be periodically back-flushed to permit the separation of the resulting solids from the main wastewater stream.

Contamination - A general term signifying the introduction into water of microorganisms, chemicals, wastes or sewage which renders the water unfit for its intended use.

Contracted Weir - A V-notch or other shaped cross-section weir for the purpose of flow measurement, as opposed to a broad width weir for the purpose of level control.

Contraction - (1) The extent to which the cross-sectional area of a jet, nappe, or stream is decreased after passing an orifice, weir, or notch. (2) The reduction in cross-sectional area of a conduit along its longitudinal axis.

Control Section - The cross-section in a waterway which is the bottleneck for a given flow and which determines the energy head required to produce the flow.

Corporation Cock -A valve for joining a service pipe to a street water main; it is generally owned and operated by the water utility or department. It cannot be operated from the surface.

Countercurrent Efficiency (Activated Carbon) - The unique advantage of a carbon column that permits spent antivated carbon to adsorb impurities before the semi-processed stream comes in contact with fresh carbon. This allows the maximum capacity of the activated carbon to be utilized.

Crest - The top of a dam, spillway, or weir, to which water must rise before passing over the structure.

Critical Bed Depth (Activated Carbon) - In a carbon column the critical bed depth is the depth of granular carbon which is partially spent. It lies between the fresh carbon and the spent carbon and is the zone where adsorption takes place. In a single-column system this is the amount of carbon that is not completely utilized.

Cross Connection - A water supply network and/or wastewater collection system which as been designed so as to prevent "cross-connections" which could result in functional damage to the system. The simpliest system is to have two separate systems, but this would not be justified if intersystems usage occurs only occasionally, hence back-flow preventers and other means are often used.

Cross-Sectional Bed Area (Activated Carbon) - The area of activated carbon through which the stream flow is perpendicular.

Curb Cock - A shutoff valve attached to the water service pipe from the water basin to the building installed near the curb, which may be operated by means of a dye key to start or stop flow in the water supply lines of a building.

Current Meter - A device for determining the velocity of moving water.

Curve, Oxygen, Sag - A curve that represents the profile of dissolved oxygen connect along the course of a stream, resulting from deoxygenation associated with biochemical oxidation of organic matter and reoxygenation through the absorption of atmospheric oxygen and through biological photosynthesis.

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 relationships 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.

Dechlorination Process - A process by which excess chlorine is removed from water to a desired level, eg. 0.1 mg/l maximum limit. Usually accomplishment by chemical reduction, by passage through carbons beds or by aeration at a suitable pH.

Degreasing - The process of removing greases and oils from sewage, waste, and sludge.

Demand, Biochemical Oxygen (BOD) - The quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time period and at a specified temperature. It is not related to the oxygen requirements in chemical combustion being determined entirely by the availability of the material as a biological food and the amount of oxygen by the microorganisms during the oxidation.

Desorption - The opposite of adsorption. A phenomenon where an adsorbed molecule leaves the surface of the adsorbent.

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.

Dialysis - The separation of a colloid from a substance in true solution by allowing the solution to diffuse through a semi-permeable membrane.

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.

Differential Gauge - A pressure gauge used to measure the difference in pressure between two points in a pipe or receptacle containing a liquid.

Diffuser - A porous plate or tube through which air is forced and divided into minute bubbles for diffusion in liquids. Commonly made of carborundum, alundum and silica sand.

Diffusion, Ridge and Furrow Air - A method of diffusing in an aeration tank of the activated sludge process, where porous tile diffusers are placed in depressions treated by the sawtooth construction of the tank bottom, in rows across the tank at right angles to the direction of flow.

Diffusion, Spiral Flow Air - A method of diffusing air in a aeration tank of the activated sludge process, where by means of properly designed baffles and the proper location of diffusers, a spiral helieal movement is given to both the air and the liquor in the tank.

Digestion - The biochemical decomposition of organic matter which results in the formation of mineral and simpler organic compounds.

Disinfection - (1) The killing of the larger portion (but not necessarily all) of harmful and objectionable microorganisms in or on a medium by means of chemicals, heat, ultraviolet light, etc. (2) The use of a chemical additive or other treatment to reduce the number of bacteria particularly the pathogenic organisms.

Dissolved Oxygen (DO) - The oxygen dissolved in sewage, water, or other liquid, usually expressed in miligrams per liter or percent of saturation. It is the test used in BOD determination.

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.

Drinking Water Standards - Standards defined by law and applied to the quality of drinking water.

Educator (Activated Carbon) - A device with no moving parts used to force an activated carbon water slurry through pipes to the desired location.

Effluent - (1) A liquid which flows out of a containing space (2) sewage, water or other liquid, partially or case may be, flowing out of a reservoir basin, or the use may be flowing out of a reservoir basin, or treatment plant or part thereof.

Electrical Conductivity - The reciprocal of the resistance in ohms measured between opposite faces of centimeter cube of an aqueous solution at a specified temperature. It is expressed as microohms per centimer at temperature degrees Celsius.

Elutriation - A process of sludge conditioning in which certain constituents are moved by successive flushing with fresh water or plant effluent thereby reducing the need for using conditioning chemicals.

Emergency Procedures - These various special procedures necessary to protect the environment from wastewater treatment plant failures due to power outages, chemical spills, equipment failures, major storms and floods, etc.

Emulsion Breaking - The method of preventing the carryover of oils from one process to another by eliminating free oil by flotation, and emulsions by the addition of aluminum or ferrous sulfate.

End Contraction - (1) The extent of the reduction in the width of the nappe due to a constriction caused by the ends of the weir notch. (2) The walls of a weir notch which does not extend across the entire width of the channel of approach.

Energy Head - The height of the hydraulic grade line above the center line of a conduit plus the

Equalization Tank - A capacity used to equalize wastewater flows or pollutant concentrations in effluents thus distributing it more evenly by hours or days.

Euetrophic Conditions - Lake water quality degradation by enrichment of nutrients resulting in characteristics undersirable for means use of water. Plant growth in forms of microscopic algae and rooted aquatic weeds become prevelent in such situations.

Fats (Wastes) - Triglyceride esters of fatty acids. Erroneously used as synonomous with grease.

Faculative - Having the power to live under different conditions either with or without oxygen.

Feeder, Chemical Dry - A mechanical device for applying dry chemicals to water sewage at a rate controlled manually or automatically by the rate of flow.

Feeder Chemical Solution - A mechanical device for applying chemicals in liquid to water and sewage at a rate controlled manually or automatically by the rate of 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 artifical 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 aerotic 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 in thick and resting on a supporting bed of gravel or a porous medium such as carborundum. The filrate 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 agitition during backwashing to remove mud and other impurities that are lodged in the sand.

Filter, Roughing - A sewage filter of relatively coarse material operated at a high rate as a preliminary treatment.

Filter, Trickling - A filter consisting of an artifical bed of coarse material, such as broken stone, clinkers, slats, or brush over which sewage is distributed and applied in drops, films, or spray, from troughs, drippers moving distributors or fixed nozzles and through which it trickles to the underdrain giving opportunity for the formation of zoogleal slimes which clarify and oxidize the sewage.

Filter, Vacuum - A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth revolving with apartial sumergence 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 continously.

Filtration, Biological - The process of passing a liquid through a biological filter containing media on the surfaces of which zoogleal films develop which absorb and adsorb fine suspended colloridal and dissolved solids and which release various biochemical end products.

Float Gauge - A device for measuring the elevation of the surface of a liquid, the actuating element of which is a buoyant float that rests on the surface of the liquid and rises or falls with it. The elevation of the surface is measured by a chain or tape attached to the float.

Floc - A very fine, fluffy mass formed by the aggregation of fine suspended particles.

Flocculator - An apparatus designed for the formation of floe in water or sewage.

Flocculation - In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

Floatation - The rising of suspended matter to the surface of the liquid in a tank as scum by aeration, the evolution of gas, chemicals, electrolysis, heat, or bacterial decomposition and the subsequent removal of the scum by skimming.

Flowrate - Usually expressed as liters/minute (gallons/minute) or liters/day (million gallons/day). Design flowrate is that used to size the wastewater treatment process. Peak flowrate is 1.5 to 2.5 times design and relates to the hydraulic flow limit and is specified for each plant. Flowrates 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 than uses as an indication of the rate of flow.

Flow-Proportioned Sample - A sampled stream whose pollutants are attributed to contributing streams in proportion to the flow rates of the contributing streams.

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 set time nor flow.

Grease - In wastewater, a group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils, and certain other nonfatty materials. The type of solvent and method used for extraction should be stated for quantification.

Grease Skimmer - A device for removing floating grease or scum from the surface of wastewater in a tank.

Grit - The heavy matter in water or sewage such as sand, gravel and cinders.

Grit Chamber - A detention chamber or an enlargement of a sewer designed to reduce the velocity of flow of the liquid to permit the separation of mineral from organic solids by differential sedimentation.

Hardness - A characteristic of water, imparted by salts of calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides, and nitrates that cause 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 Adsorption - The heat given off when molecules are adsorbed.

Heavy Metals - A general name given to the ions of metallic elements such as copper, zinc, chromium, and aluminum. They are normally removed from a wastewater forming an insoluble precipitate (usually a metallic hydroxide).

Hook Gauge - A pointed, U-shaped hoot attached to a graduated staff or vernier scale, used in the accurate measurement of the elevation of a water surface. The hook is submerged, and then raised, usually by means of a screw, until the point just makes a pimple on the water surface.

Hydraulic Surge - A pressure increase in a pipeline which accompanies a sudden decrease in the flow velocity. In some cases this increased pressure may cause rupture of the pipe.

Industrial Wastes - The liquid wastes from industrial processes as distinct from domestic or sanitary wastes.

Incineration - The combustion (by burning) of organic matter in wastewater sludge solids after water evaporation from the solids.

Index, Sludge - The volume of mililiters occupied by aerated mixed liquor containing 1 gram of dry solids after settling 80 min. commonly referred to as the Mohlman index. The Donaldson index which is also commonly used is obtained by dividing 100 by the Mohlman index.

Influent - Sewage, water or other liquid, either raw or partly treated, flowing into a reservoir basin, or treatment plant or any part thereof.

Invert - The floor, bottom or lowest portion of the internal cross section of a closed conduit.

Iodine Number (Activated Carbon) - The iodine number is the miligrams of iodine adsorbed 1 gram of carbon at a filtrate concentration of 0.02N iodine.

Ionization - The process of the formation of ions by the splitting of molecules of electrolytes in solution.

Irrigation Spray - Irrigation by means of nozzles along a pipe on the ground or from perforated overhead pipes.

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 anaerobic stabilization occurs.

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.

Liquor, Mixed - A mixture of activated sludge and sewage in the aeration tank undergoining activated sludge treatment.

Liquor, Supernatant - (1) The liquor overlying deposited solids. (2) the liquid in a sludge digestion tank which lies between the sludge at the bottom and the floating scum at the top.

Loss of Head Gage - A gage on a rapid sand filter which indicates the loss of head involved in the filtering operation whereby the operator is able to ascertain the need for filter backwashing.

Macropore - The pores in activated carbon which are larger (diameter) than 1.000A.

Makeup Carbon - Fresh granular activated carbon which must be added to a column system after a regeneration cycle or when deemed necessary to bring the total amount of carbon to specification.

Manometer - An instrument for measuring pressure. It usually consists of a U-shaped tube containing a liquid the surface of which is one end of the tube moves proportionally with changes in pressure on the liquid in the other end. Also, a tube type of differential pressure gauge.

Mean Volocity - 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.

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.

Methylene Blue Number (Activated Carbon) - The methylene blue number is the milligrams of methylene blue adsorbed by 1 gram of carbon in equilibrium with a solution of methylene blue having a concentration of 1.0 mg/l.

Methylorange Alkalinity - A measure of the total alkalinity of an aqueous suspension or solution. It is measured by the quantity of sulfuric acid required to bring the water pH to a value of 4.3 as indicated by the change in color of methyl orange. It is expressed in miligrams $CACO_3$ per liter.

Micropore - The pores in activated carbon which range in size (diameter) from 10 to 1,000 A.

Miligrams Per Liter (mg/l) - This is a weight per volume designation used in water and wastewater analysis.

Mixed Media Filtration - A filter which uses 2 or more filter materials of differing specific gravities selected so as to produce a filter uniformly graded from coarse 1.. fine.

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 continous, of water quality.

Most Probable Number (MPN) - That number of organisms per unit volume that, in accordance with statistical theory, would be more likely than any other number to yield the obserbed test result with the greatest frequency. Expressed as desnity of organisms per 100 ml. Results are computed from the number of positive findings of coliform-group organisms resulting from multiple-portion decimal-dilution plantings.

Nappe - The sheet or curtain of water overflowing a weir or dam. When freely overflowing any given structure, it has a well-defined upper and lower surface.

Neutralization - Reaction of acid or alkali with the opposite reagent until the concentrations of hydrogen and hydroxyl ions in solution are approximately equal.

Nitrification - The conversion of nitrogenous matter into nitrates by bacteria.

Nonionic Surfactant - A general family of surfactants so called because in solution the entire molecule remains associated. Nonionic molecules orient themselves at surfaces not by an electrical charge, but through separate grease-solubilizing and water-soluble groups within the molecule.

Nonsettleable Matter - The suspended matter which does not settle nor float to the surface of water in a period of one hour.

Nonsettleable Solids - Wastewater matter that will stay in suspension for an extended period of time. Such period may be arbitrarily taken for testing purposes as one hour.

Notch - An opening in a dam, spillway, or measuring weir for the passage of water.

Nozzle - (1) A short, cone-shaped tube used as an outlet for a hose or pipe. The velocity of the merging stream of water is increased by the reduction in cross sectional area of the nozzle (2) a short piece of pipe with a flange on one end and a saddle flange on the other end.

Nutrients - Materials which are considered to be essential to support biological life.

Odor Control - The elimination of odor-causing valatile substances associated with organic matter, living organisms, and cases. The most common, control measurement in use are the application of activated carbon residual chlorination, chlorine dioxide, ozone and aeration.

Odor Threshold - The point at which after successive dilutions with odorless water, the odor of a water sample can just be detected. The threshold odor is expressed quantitatively by the number of times the sample is diluted with odorless water.

Oil and Grease - Those materials which are exgractable from wastewater with hexane, chloroform if other content of these specific solvents pollutants in water or wastewater (in mg/l of ppm) which can significantly influence the environment.

Open-Channel Flow - Flow of a fluid with its surface exposed to the atmosphere. The conduit may be an open channel or a closed conduit flowing partly full.

Operation Qualifications, Treatment Plant - Usually defined by a licence issued by local authorities.

Organic Matter - Chemical substances of animal or vegetable origin, or more correctly of basically carbon structure, comprising compounds consisting of hydrocarbons and their deviations.

Organic Nitrogen - Nitrogen combined in organic molecules such as protein, amines, and amino acids.

Orifice - (1) An opening with closed perimeter, usually of regular form, in a plate, wall, or partition, through which water may flow generally used for the purpose of measurement of control of such water. The edge may be sharp or of another configuration (2) the end of a small tube such as a Pitot tube.

Orifice Plate - A plate containing an orifice. In pipes, the plate is usually inserted between a pair of flanges, and the orifice is smaller in area than the cross section of the pipe.

Orthophosphate - An acid or salt containing phosphorus as PO_4.

Outfall - The point or location where sewage or drainage discharges from a sewer, drain, or conduit.

Overflow Storm - A weir, orifice, or other device for permitting the discharge from a combined sewer of that part of the flow in escess of that which the sewer is designed to carry.

Oxidation - The addition of oxygen to a compound. More generally, any reaction which involves the loss of electrons from an atom.

Oxidation Pond - A basin used for retention of wastewater before final disposal, in which biological oxidation of organic material is effected by natural or artifically accelerated transfer of oxygen to the water from air.

Oxidation Reduction Potential (ORP) - The potential required to transfer electrons from the oxidant to the reductant and used as a qualitative measure of the state of oxidation in wastewater treatment systems.

Oxygen Consumed - The quantity of oxygen taken up from potassium permananganate in solution by a liquid containing organic matter. Commonly regarded as an index of the carbonaceous matter present. Time and temperature must be specified.

Oxygen Dissolved - Usually designated as DO. The oxygen dissolved in sewage water, or othe rliquid usually expressed in parts per million or percent of staturation.

Ozone - Oxygen in molecular form with three atoms of oxygen forming each molecule. Atmospheric oxygen is in molecular form but each molecule contains two atoms of oxygen. Ozone is formed by passing high voltage electric charges through dry air. The third atom of oxygen in each molecule of ozones is loosely bound to it and is easily released.

Parshall Flume - A calibrated device developed by Parshall for measuring the flow of liquid in an open conduit. It consists essentially of a contracting length, a throat, and an expanding length. At the throat is a sill over which the flow passes as critical depth. The upper and lower heads are each measured at a definite distance from the sill. The lower head not be measured unless the sill is submerged more than about 67 percent.

Pathogenic Bacteria - Bacteria which may cause disease in the organisms by their parasitic growth.

pH - The reciprocal of the logarithm of the hydrogen ion concentration. The concentration is the weight of hydrogen ions, in grams per liter of solution. Neutral water, for example, has a pH value of 7 and hydrogen ion concentration of 10.7.

pH Adjustment - A means of maintaining the optimum pH through the use of chemical additives. Can be manual or automatic, or automatic with flow corrections pH adjustment is not a linear function.

Phenolein Alkalinity - A measure of the hydroxides plus one half of the normal carbonates in aqueous suspension. Measured by the amount of sulfuric acid required to bring the water to a pH value of 8.3, as indicated by a change in color of phenolphthalein. It is expressed in parts per million of calcium carbonate.

Pitot Tube - A device for measuring the velocity of flowing fluid by using the velocity head of the stream as an index velocity. It consists essentially of an orifice held to point upstream and connected with a tube in which the impact pressure due to velocity head may be observed and measured. It also may be constructed with an upstream and downstream orifice, or with an orifice pointing upstream to measure the velocity head or pressure and piezometer holes in a coaxial tube to measure the static head or pressure, in which case the difference in pressure is the index of velocity.

Pollution Load - A measure of the strength of a wastewater in terms of its solids or oxygen-demanding characteristics, or in terms of harm to receiving waters.

Pollution Water - The introduction into a body of water of substances of such character and of such quantity that its natural quality is so altered as to impair its usefulness or render it offensive to the senses of sight, taste, or smell.

Polyelectrolytes - Used as a coagulant or a coagulant aid in water and wastewater treatment (activated carbon is another coagulant aid). They are synthetic polymers having a high molecular weight. Anionic negatively charged. Nonionic carry both negative and positive charges (Cationic postively charged most popular).

Pond, Sewage Oxidation - A pond either natural or artifical into which partly treated sewage of discharged and in which natural purification processes take place under the influence of sunlight and air.

Pooling, Filter - The formation of pools of sewage on the surface of filters, caused by surface cloggings.

Pore Volume (activated carbon) - The pore volume is the difference in the volumetric displacement by granular activated carbon in mercury and in helium at standard conditions.

Preaeration - A preparatory treatment of sewage consisting of aeration to remove gases, add oxygen, or promote flotation of grease and aid coagulation.

Prechlorination - (1) Chlorination of water prior to filtration. (2) Chlorination of sewage prior to treatment.

Precipitation, chemical - (1) Precipitation induced by addition of chemicals (2) The process of softening water by the addition of lime and soda ash as the precipitants.

Pretreatment - Any wastewater treatment process used to reduce pollution load partially before the wastewater is introduced into a main sewer system or delivered to a treatment plant for substantial reduction of the pollution load.

Primary Treatment - A process to remove substantially all floating and setteable solids in wastewater and partially to reduce the concentration of suspended solids.

Probability Curve - A curve that expresses the cumulative frequency of occurrence of a given event, based on an extended record of past occurrences. The curve is usually plotted on specially prepared coordinate paper, with ordinates representing magnitude equal to, or less than, the event, and abscissas representing the probability, time, or other units of incidence.

Process Activated Sludge - A biological sewage treatment process in which a mixture of sewage and activated sludge is agitated and aerated. The activated sludge is subsequently separted from the treated sewage (mixed liquor) by sedimentation, and wasted or returned to the process as needed. The treated sewage overflows the weir of the settling tank in which separation from the sludge takes place.

Process, Biological - The process by which the life activities of bacteria, and other microorganisms in the seach for food break down complex organic materials into simple, more stable substances. Self-purification of sewage polluted streams, sludge digestion, and all so-called secondary sewage treatments result from this process. Also called biochemical process.

Process, Oxidation - Any method of sewage treatment for the oxidation of the putrescible organic matter the usual methods are biological filtration, and the activated sludge process.

Purification Degree - (1) A measure of the completness of destruction or removal of objectionable impurities. such as bacteria and hardness from water by natural means (self-puriciation) or by treatment (2) A measure of the removal, oxidation, or destruction of solids organic matter, bacteria, or other specified substance effected by sewage treatment processes.

Putrefaction - Biological decomposition of organic matter accompanied by the production of foul-smelling associated with anaerobic conditions.

Rate Oxidation - The rate at which the organic matter in sewage is stablized.

Ratio Dosing - The maximum rate of application of sewage to a filter on any unit of area, divided by the average rate of application on that area.

Reactivation (activated carbon) - The removal of adsorbates from spent granular activated carbon which will allow the carbon to be reused. This is also called regeneration and revivfication.

Reaeration Sludge - The continous aeration of sludge after its intial aeration in the activated sludge process.

Recirculation - The refiltration of all or a portion of the effluent in a high rate trickling filter for the purpose of incoming flow to reduce its strength.

Reduction Overall - The percentage reduction in the final effluent as compared with the raw sewage.

Reoxygenation - The replenishment of oxygen in a stream from (1) dilution water entering the stream (2) biological oxygenation through the activities of certain oxygen producting plants and (3) atmospheric reaeration.

Reservoir - A pond, lake, tank, basin, or other space either natural in origin or created in whole or in part by building of engineering structures. It is used for storage, regulation, and control of water.

Recorder - A device that makes a graph or other automatic record of the stage, pressure, depth, velocity, or the movement or position of water controlling devices, usually as a function of time.

Recovery Products - Substances regarded as wastewater pollutants which are recovered for their potential value through sale or reuse; recovery often is used to lower or partially offset treatment (or recovery) costs.

Rectangular Weir - A weir having a notch that is rectangular in shape.

Reduction Practices - (1) Wastewater reduction practices can mean the reduction of water usage to lower the volume of wastewater requiring treatment and (2) the use of chemical reductant materials to lower the valance state of a specific wastewater pollutant.

Reduction Treatment - The opposite of oxidation treatment where in a reductant (chemical) is used to lower the valence state of a pollutant to a less toxic form e.g. the use of SO2 to "reduce" chromium +6 to chromium +3 in an acidic solution.

Refractory Organics - Organic pollutants which are chemically oxidation, e.g. DDT pesticide.

Residual Chlorine - Chlorine remaining in water or wastewater at the end of specified contact period as combined or free chlorine.

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 an aliquot portion of water or waste for analytical purposes. May be designed for taking a single sample (grab), composite sample, continous sample, periodic sample.

Sanitary Sewer - A sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions together with minor quantities of ground-storm, and surface waters that are not admitted intentionally.

Screen - (1) A device with openings, generally of uniform size, used to retain or remove suspended or floating solids in flowing water or wastewater and to prevent them from entering an intake or passing a given point in a conduit. The screening element may consist of parallel bars, rods, wires, grating, wire mesh, or perforated plate, and the openings may be of any shape, although they are usually circular or rectangular. (2) A device used to segregate granular material such as sand, crushed rock, and soil into various sizes.

Secondary Settling Tank - A tank through which effluent from some prior treatment process flows for the purpose of removing settleable solids.

Secondary Wastewater Treatment - The treatment of wastewater by biological methods after primary treatment by sedimentation.

Second Stage Biological Oxygen Demand - That part of the oxygen demand associated with the biochemical oxidation of nitrogenous material. As the term implies, the oxidation of the nitrogenous materials usually does not start until a portion of the carbonaceous material has been oxidized during the first stage.

Sedimentation - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usally accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling.

Seeding Sludge - The inoculation of undigested sewage solids with sludge that has undergone decomposition for the purpose of introducing favorable organisms, thereby accelerating the intial stages of digestion.

Sewage Combined - A sewage containing both sanitary sewage and surface or storm water with or without industrial wastes.

Sewage Dilute - Sewage containing less than 150 ppm of suspended solids and BOD (weak sewage).

Sewage Industrial - Sewage in which industrial wastes predominate.

Sewage Raw - Sewage prior to receiving any treatment.

Sewage Settled - Sewage from which most of the settleable solids have been removed by sedimentation.

Sewage Storm - Liquid flowing in sewers during or following a period of heavy rainfall and resulting therefrom.

Sewer - A pipe or conduit, generally closed, but normally not flowing full for carrying sewage and other waste liquids.

Sewer Intercepting - A sewer which receives dry-weather flow from a number of transverse sewers or outlets, and fequently additional, predetermined quantities of storm water (if from a combined system) and which conducts such waters to a point for treatment or disposal.

Semipermeable Membrane - A barrier, usually thin, that permits passage of particles up to a certain size or of special nature. Often used to separate colloids from their suspending liquid, as in dialysis.

Settleable Solids - (1) That matter in wastewater which will not stay in suspension during a preselected settling period, such as one 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 one hour.

Skimming Tank - A tank so designed that floating matter will rise and remain on the surface of the wastewater until removed, while the liquid discharges continously under certain walls or scum boards.

Sludge - The solids (and accompanying water and organic matter) which are separated from sewage or industrial wastewater in treatment plant facilities. Sludge separation and disposal is one of the major expenses in wastewater treatment.

Sludge Conditioning - A process employed to prepare sludge for final disposal can be thickening, digesting, heat treatment etc.

Sludge Digestion - The process by which organic or volatile matter in sludge is gasified, liquidfied, mineralized, or converted into more stable organic matter through the activities of either anaerobic or aerobic organisms.

Sludge Disposal - The final disposal of solid wastes including the use of sewage sludges as fertilizers and soil builders; dumping sludge at sea; and filling lowlying lands.

Sludge thickening - The increase in solids concentration of sludge in a sedimentation of digestion tank.

Spills - A chemical or material spill is an unintentional discharge of more than 10 percent of the sewage daily usage of a regularly used substance. In the case of a rarely used (one per year or less) chemical or substance, a spill is that amount that would result in 10% added loading to the normal air, water or solid waste loadings measured as the closest equivalent pollutant.

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 effected by natural or artifically accelerated transfer of oxygen to the water from air.

Staff Gauge - A graduated scale, vertical unless otherwise specified, on a plank, metal plate, pier, wall etc., used to indicate the height of a fluid surface above a specified point or datum plane.

Stage Discharge Relation - The relation between gauge height and discharge of a stream or conduit at a gaugint station. This relation is shown by the rating curve or rating table for such stations.

Static Head - (1) The total head without reduction for velocity head or losses; for example, the difference in the elevation of headwater and tail water of a power plant. (2) The vertical distance between the free level of the source of supply and the point of free discharge or the level of the free surface.

Steady Flow - (1) A flow in which the rate or quantity of water passing a given point per unit of time remains consrant. (2) Flow in which the velocity vector does not change in either magnitude or direction with respect to time at any point or section.

Steady Uniform Flow - A flow in which the velocity and the quantity of water flowing per unit remains constant.

Stilling Well - A pipe, chamber, or compartment with compartively small inlet or inlets communicating with a main body of water. Its purpose is to dampen waves or surges, while permitting the water level within the well to rise and fall with the major fluctations of the main body of water. It is used with watermeasuring devices to improve accuracy of measurement.

Submerged Weir - A weir that when in use, has the water level on the downstream side at an elevation equal to or higher than, the weir crest. The rate of discharge is affected by the tail water. Also called drowned weir.

Suppressed Weir - A weir with one or both sides flush with the channel of approach. This prevents contraction of the nappe adjacent to the flush side. The suppression may occur on one end or both ends.

Surveys - The gathering of numerical and other forms of data from the field, or plant site for the subsequent purpose of data reduction, correlation and analysis leading to improve water supply, treatment, use and wastewater treatment, described in total as a Water Management Program.

Suspended Matter - (1) Solids in suspension in water, wastewater or effluent. (2) Solids in suspension that can be removed readily by standard filtering procedures in a laboratory. Suspended Solids- (1) Solids that 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.

Tertiary Treatment - A process to remove practically all solids and organic matter from wastewater. Granular activated carbon filtration is a tertiary treatment process. Phosphate removal by chemical coagulation is also regarded as a step in tertiary treatment.

Threshold Odor - The minimum odor of the water sample that can just be detected after successive dilutions with odorless water. Also called odor threshold.

Titration - The determination of a constituent in a known volume of solution by the measured addition of a solution of known strength to completion of the reaction as signaled by observation of an end point.

Total Organic Carbon (TOC) - TOC is a measure of the amount of carbon in a sample originating from organic matter only. The test is run by burning the sample and measuring the CO produced.

Tracer - (1) A foreign substance mixed with or attached to a given substance for the determination of the location or distribution of the substance. (2) An element or compound that has been made radioactive so that it can be easily followed (traced) in biological and industrial processes. Radiation emitted by the radioisotope pinpoints its location.

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 absorption 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.

Ultimate Biochemical Oxygen Demand - (1) Commonly, the total quantity of oxygen required to satisfy completely the first-stage biochemical oxygen demand. (2) More strickly, the quantity of oxygen required to statisfy completly both the first-stage and the second-stage biochemical oxygen demands.

Velocity Area Method - A method used to determine the discharge of a stream or any open channel by measuring the velocity of the flowing water at several points within the cross section of the stream and summing up the products of these velocities and their respective fraction of the total area.

Velocity Meter - A water meter that operates on the principle that the vanes of the wheel move at approximately the same velocity as the flowing water.

Velocity of Approach - The mean velocity in a conduit immediately upstream from a weir, dam, venturi tube, or other structure.

Vena Contracta - The most contacted sectional area of a stream jet, or nappe issuing through or over an orifice or weir notch. It occurs downstream from the plane of such notch or orifice.

Venturi Flume - A open flume with a contracted throat that causes a drop in the hydraulic grade line. It is used for measuring flow.

Venturi Meter - A differential meter for measuring flow of water or other fluid through closed conduits of pipes, consisting of a venturi tube and one of several proprietary forms of flow-registering devices. The difference in velocity heads between the entrance and the contracted throat is an indication of the rate of flow.

Venturi Tube - A closed conduit or pipe, used to measure the rate of fluids, containing a gradual contraction to a throat, which causes a pressure-head reduction by which the velocity may be determined. The contraction is usually, but not necessarily, followed by an enlargement to the original size.

Volatile Solids - The quantity of solids in water, wastewater or other liquids, lost on ignition of the dry solids at 600°C.

Wastewater Survey - An investigation of the quality and characteristics of each waste stream, as in an industrial plant or municipality.

Water Level Recorder - A device for producing, graphically or otherwise, a record of the rise and fall of a water surface with respect to time.

Water Meter - A device installed in a pipe under pressure for measuring and registering the quantity of water passing through it.

Water Renovation - Wastewater treatment of sufficient degree to allow the reuse of water for one or more purposes in a given water supply/treatment system.

Weir - (1) A diversion dam. (2) A device that has a crest and some side containment of known geometric shape, such as a V, trapezoid, or rectangle and is used to measure flow of liquid. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening.

APPENDIX C

METRIC UNITS

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

* Actual conversion, not a multiplier

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