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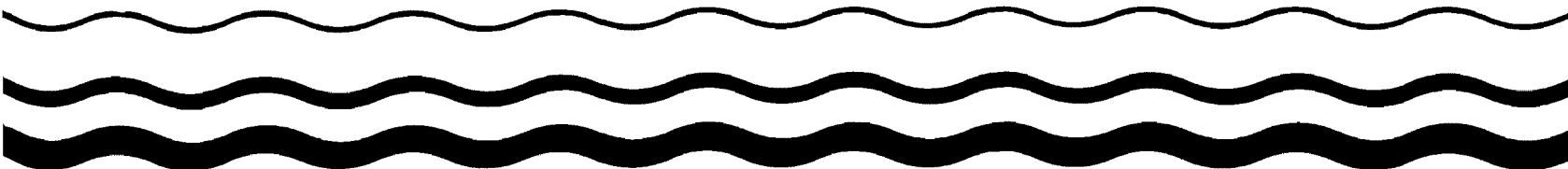# Development Document for Effluent Limitations Guidelines and Standards for the

Draft

Battery Manufacturing

Point Source Category

DEVELOPEMENT DOCUMENT

FOR

PROPOSED EFFLUENT LIMITATIONS GUIDELINES

AND

NEW SOURCE PERFORMANCE STANDARDS

FOR THE

BATTERY MANUFACTURING POINT SOURCE CATEGORY

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In order to comply with requests for confidentiality, plant identification numbers have been deleted from the text and plants are referenced by letters. The same plant does not necessarily have the same letter for every reference.

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SECTION I

CONCLUSIONS

This is a draft development document and is being circulated for review of its technical merit. This draft document is subject to corrections and revisions as appropriate prior to its issuance at the time of proposed rulemaking.

Treatment technologies for best practicable control technology currently available (BPT) and treatment options for best available technology economically achievable (BAT) for the control of toxic pollutants have been developed and are presented herein. However, no regulatory numbers have been attached. Before proposal of effluent limitations and standards, the Agency will choose among and between BAT options and will set regulatory numbers based on the final treatment technologies selected.

SECTION II

RECOMMENDATIONS

This section will be completed after the Environmental Protection Agency has made a final selection of treatment options and effluent levels preparatory to proposing a regulation.

SECTION III

INTRODUCTION

LEGAL AUTHORITY

This report is a technical background document prepared to support effluent limitations and standards under authority of Sections 301, 304, 306, 307, 308, and 501 of the Clean Water Act (Federal Water Pollution Control Act, as Amended, (the Clean Water Act or the Act). These effluent limitations and standards are in partial fulfillment of the Settlement Agreement in Natural Resources Defense Council, Inc. v. Train, 8 ERC 2120 (D.D.C. 1976), modified March 9, 1979. This document also fulfills the requirements of sections 304(b) and (c) of the Act. These sections require the Administrator, after consultation with appropriate Federal and State Agencies and other interested persons, to issue information on the processes, procedures, or operating methods which result in the elimination or reduction of the discharge of pollutants through the application of the best practicable control technology currently available, the best available technology economically achievable, and through the implementation of standards of performance under Section 306 of the Act (New Source Performance Standards).

Background

The Clean Water Act

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. By July 1, 1977, existing industrial dischargers were required to achieve effluent limitations requiring the application of the best practicable control technology currently available (BPT), Section 301(b)(1)(A); and by July 1, 1983, these dischargers were required to achieve effluent limitations requiring the application of the best available technology economically achievable --- which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants (BAT), Section 301(b)(2)(A). New industrial direct dischargers were required to comply with Section 306 new source performance standards (NSPS), based on best available demonstrated technology; and new and existing sources which introduce pollutants into publicly owned treatment works (POTW) were subject to pretreatment standards under Sections 307(b) and (c) of the Act. While the requirements for direct dischargers were to be incorporated into National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402 of the Act, pretreatment standards were made

enforceable directly against any owner or operator of any source which introduces pollutants into POTW (indirect dischargers).

Although section 402(a)(1) of the 1972 Act authorized the setting of requirements for direct dischargers on a case-by-case basis, Congress intended that, for the most part, control requirements would be based on regulations promulgated by the Administrator of EPA. Section 304(b) of the Act required the Administrator to promulgate regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of BPT and BAT. Moreover, Section 306 of the Act requires promulgation of regulations for NSPS. Sections 304(g), 307(b), and 307(c) required promulgation of regulations for pretreatment standards. In addition to these regulations for designated industry categories, Section 307(a) of the Act required the Administrator to promulgate effluent standards applicable to all dischargers of toxic pollutants. Finally, Section 501(a) of the Act authorized the Administrator to prescribe any additional regulations necessary to carry out his functions under the Act.

The EPA was unable to promulgate many of these regulations by the dates contained in the Act. In 1976, EPA was sued by several environmental groups, and in settlement of this lawsuit EPA and the plaintiffs executed a Settlement Agreement which was approved by the Court. This Agreement required EPA to develop a program and adhere to a schedule for promulgating for 21 major industries BAT effluent limitations guidelines, pretreatment standards, and new source performance standards for 65 priority pollutants and classes of pollutants. See Natural Resources Defense Council, Inc. v. Train, 8 ERC 2120 (D.D.C. 1976), modified March 9, 1979.

On December 27, 1977, the President signed into law the Clean Water Act of 1977. Although this law makes several important changes in the Federal water pollution control program, its most significant feature is its incorporation into the Act of several of the basic elements of the Settlement Agreement program for priority pollutant control. Sections 301(b)(2)(A) and 301(b)(2)(C) of the Act now require the achievement by July 1, 1984 of effluent limitations requiring application of BAT for "toxic" pollutants, including the 65 "priority" pollutants and classes of pollutants which Congress declared "toxic" under Section 307(a) of the Act. Likewise, EPA's programs for new source performance standards and pretreatment standards are now aimed principally at toxic pollutant controls. Moreover, to strengthen the toxics control program, Section 304(e) of the Act authorizes the Administrator to prescribe best management practices (BMPs) to prevent the release of toxic and hazardous pollutants from plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage associated with, or ancillary to, the manufacturing or treatment process.

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In keeping with its emphasis on toxic pollutants, the Clean Water Act of 1977 also revises the control program for non-toxic pollutants. Instead of BAT for conventional pollutants identified under Section 304(a)(4) (including biochemical oxygen demand, suspended solids, fecal coliform and pH), the new Section 301(b)(2)(E) requires achievement by July 1, 1984, of effluent limitations requiring the application of the best conventional pollutant control technology (BCT). The factors considered in assessing BCT for an industry include the costs of attaining a reduction in effluents and the effluent reduction benefits derived compared to the costs and effluent reduction benefits from the discharge of publicly owned treatment works (Section 304(b)(4)(B). For non-toxic, nonconventional pollutants, Sections 301(b)(2)(A) and (b)(2)(F) require achievement of BAT effluent limitations within three years after their establishment or July 1, 1984, whichever is later, but not later than July 1, 1987.

GUIDELINE DEVELOPMENT SUMMARY

The effluent guidelines for battery manufacturing were developed from data obtained from previous EPA studies, literature searches, and a plant survey and evaluation. Initially, information from EPA records was collected and a literature search was conducted. This information was then catalogued in the form of individual plant summaries describing processes performed, production rates, raw materials utilized, wastewater treatment practices, water uses and wastewater characteristics.

In addition to providing a quantitative description of the battery manufacturing category, this information was used to determine if the characteristics of the category as a whole were uniform and thus amenable to one set of effluent limitations and standards. Since the characteristics of the plants in the data base and the wastewater generation and discharge varied widely, the establishment of subcategories was determined to be necessary. The initial subcategorization of the category was made by using recognized battery type as the subcategory description:

- Lead Acid
- Nickel-Cadmium (Wet Process)
- Nickel-Cadmium (Dry Process)
- Carbon-Zinc (Paper)
- Carbon-Zinc (Paste)
- Mercury (Ruben)
- Alkaline-Manganese
- Magnesium-Carbon

- Carbon-Zinc (Air)
- Silver Oxide-Zinc
- Magnesium Cell
- Nickel-Zinc
- Lithium Cell
- Mercury (Weston)
- Lead Acid Reserve
- Miniature Alkaline

To supplement existing data, EPA sent a data collection portfolio (dcp) under authority of Section 308 of the Federal Water Pollution Control Act, as amended, to each known battery manufacturing company.

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In addition to existing and plant supplied information (via dcp), data were obtained through a sampling program carried out at selected sites. Sampling consisted of a screening program at one plant for each listed battery type plus verification at up to 5 plants for each type. Screen sampling was utilized to select pollutant parameters for analysis in the second or verification phase of the program. The designated priority pollutants (65 toxic pollutants) and typical battery manufacturing pollutants formed the basic list for screening. Verification sampling and analysis was conducted to determine the source and quantity of the selected pollutant parameters in each subcategory.

Conventional nomenclature of batteries provided little aid in development of effluent limitations and standards. SIC groupings are inadequate because they are based on the end use of the product, not composition of the product, or manufacturing processes. Based upon the information provided by the literature, dcp and the sampling program, the initial approach to subcategorization using battery type was reviewed. Of the initial 16 battery types no production of mercury (Weston) cells was found. The miniature alkaline type was dropped because it is not a specific battery type but merely a size distinction involving several battery types (e.g., alkaline-manganese, silver oxide-zinc, and mercury-zinc (Ruben). In addition to the original battery types the dcp's disclosed seven additional battery types (silver chloride-zinc, silver oxide-cadmium, mercury-cadmium, mercury and silver-zinc, mercury and cadmium-zinc, thermal and nuclear). Nuclear batteries, however, have not been manufactured since 1978. Since they constitute a distinct subcategory, they have been included in subcategorization discussion, but are not otherwise considered in this document. Mercury and silver-zinc batteries have not been manufactured since 1977, but do not constitute a single subcategory and therefore will be discussed where appropriate. The other five additional battery types are considered in this document.

An analysis of production methods, battery structure and electrolytic couple variations for each battery type revealed that there are theoretically about 600 distinct variations that could require further subgrouping. Based upon dcp responses and actual plant visits, over 200 distinct variations have been positively identified. Because of the large number of potential subgroupings associated with subcategorization by battery type, a subcategorization basis characterizing these variations was sought. Grouping by anode material accomplishes this objective and results in the following subcategories:

Anode Material	Designation For This Document
• Cadmium Anode	Cadmium
• Calcium Anode	Calcium
• Lead Anode	Lead
• Zinc Anode, Acid Electrolyte	Leclanche
• Lithium Anode	Lithium
• Magnesium Anode	Magnesium
• Zinc Anode, Alkaline Electrolyte	Zinc
• Radioisotopes	Nuclear

As is discussed fully in Section IV, the zinc anode is divided into two groups based on electrolyte type because of substantial differences in manufacture and wastes generated by the two groups. As detailed in Section IV and V, further segmentation using a matrix approach is necessary to fully detail each subcategory. Specific manufacturing process elements requiring control for each subcategory are presented in Section IV followed by a detailed technical discussion in Section V.

After establishing subcategorization, the available data were analyzed to determine wastewater generation and mass discharge rates in terms of production for each subcategory. In addition to evaluating pollutant generation and discharges, the full range of control and treatment technologies existing within the battery manufacturing category was identified. This was done considering the pollutants to be treated and the chemical, physical and biological characteristics of these pollutants. Special attention was paid to in-process technology such as the recovery and reuse of process solutions, the recycle of process water and the curtailment of water use.

The information as outlined above was then evaluated in order to determine what levels of technology were appropriate as a basis for effluent limitations for existing sources based on the best practicable control technology currently available (BPT) and based on best available technology economically achievable (BAT). Levels of technology appropriate for pretreatment of wastewater introduced into a publicly owned treatment works (POTW) from both new and existing sources were also identified as were the new source performance standards (NSPS) based on best demonstrated control technology, processes, operating methods, or other alternatives (BDT) for the control of direct discharges from new sources. Where appropriate, the data were also used to identify the best conventional pollutant control technology (BCT), although the presence of toxic metals in most waste streams may limit applicability of these techniques. In evaluating these technologies various factors were considered. These included treatment technologies from other industries, any pretreatment requirements, the total cost of application of the technology in relation to the effluent reduction benefits to be

achieved, the age of equipment and facilities involved, the processes employed, the engineering aspects of the application of various types of control technique process changes, and non-water quality environmental impact (including energy requirements).

Sources of Industry Data

Data on the battery manufacturing category were gathered from literature studies, previous industry studies by the Agency, a plant survey and evaluation, and inquiries to waste treatment equipment manufacturers. These data sources are discussed below.

Literature Study - Published literature in the form of books, reports, papers, periodicals, and promotional materials was examined. The most informative sources are listed in Section XIV. The material research covered battery chemistry, the manufacturing processes utilized in producing each battery type, waste treatment technology, and the specific market for each battery type.

EPA Studies - A previous preliminary and unpublished EPA study of the battery manufacturing segment was reviewed. The information included a summary of the industry describing: the manufacturing processes for each battery type; the waste characteristics associated with this manufacture; recommended pollutant parameters requiring control; applicable end-of-pipe treatment technologies for wastewaters from the manufacture of each battery type; effluent characteristics resulting from this treatment; and a background bibliography. Also included in these data were detailed production and sampling information on approximately 20 manufacturing plants.

Plant Survey and Evaluation - The collection of data pertaining to facilities that manufacture batteries was a two-phased operation. First, a mail survey was conducted by EPA. A dcp was mailed to each company in the country known or believed to manufacture batteries. This dcp included sections for general plant data, specific production process data, waste management process data, raw and treated wastewater data, waste treatment cost information, and priority pollutant information based on 1976 production records. A total of 226 dcp's were mailed. From this survey, it was determined that 133 companies were battery manufacturers, including full line manufacturers and assemblers. Of the remaining 93 data requests that were mailed, 9 companies were no longer manufacturing batteries, 15 were returned as undeliverable, and 69 were in other business areas. Some plants responded with 1977 or 1978 data, and some provided 1976 data although production has subsequently ceased. Table III-1 summarizes the survey responses received in terms of number of plants which provided information in each subcategory. Another column was added to include information obtained in the survey, by phone or by actual plant visit, that a plant was no longer active in a

subcategory. The total number of plant responses is larger than the 133 company responses, since many companies own more than one plant and information was requested on each plant owned or operated by the company. Also, some plants manufacture batteries in more than one subcategory, and currently four plants are active in three subcategories and nine plants are active in two subcategories. Due to changes in ownership and changes in production lines, the number of companies and also the number of plant sites active in the category often vary. The result is that about 230 plant sites are currently included in this category. All information received was reviewed and evaluated, and will be discussed as appropriate in subsequent sections.

TABLE III-1

SURVEY SUMMARY

SUBCATEGORY	NUMBER OF PLANTS (Information Received)	NUMBER OF PLANTS (Currently Active)
Cadmium	13	10
Calcium	3	3
Lead	184*	184*
Leclanche	20	19
Lithium	7	7
Magnesium	8	8
Nuclear	1	0
Zinc	17	16
Totals	253	247

Total Number of Plant Sites in Category - 230.

*Includes plate manufacturers and assemblers.

The second phase of the data collection effort included the visitation of selected plants, for screening and verification sampling of wastewaters from battery manufacturing operations. The dcp's served as a primary source in the selection of plants for visitation and sampling. Specific criteria used to choose visitation sites included:

1. Distributing visits according to the type of battery manufactured.

2. Distributing visits among various manufacturers of each battery type.

3. Selecting plants whose production processes were representative of the processes performed at many plants for each subcategory. Consideration was also given to the understanding of unique

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processes or treatment not universally practiced but applicable to the industry in general.

4. A plant's knowledge of its production processes and waste treatment system as indicated in the dcp.

5. The presence of wastewater treatment or water conservation practices.

Forty plants were visited and a wastewater sampling program was conducted at nineteen of these plants. The sampling program at each plant consisted of two activities: first, the collection of technical information, and second, water sampling and analysis. The technical information gathering effort centered around a review and the completion of the dcp to obtain historical data as well as specific information pertinent to the time of the sampling. In addition to this, the following specific technical areas were covered during these visits.

1. Water use for each process step and waste constituents.

2. Water conservation techniques.

3. In-process waste treatment and control technologies.

4. Overall performance of the waste treatment system and future plans or changes anticipated.

5. Particular pollutant parameters which plant personnel thought would be found in the waste stream.

6. Any problems or situations peculiar to the plant being visited.

7. BCT practices at the plant being visited.

All of the samples collected were kept on ice throughout each day of sampling. At the end of each day, samples were preserved according to EPA protocol and sent to laboratories for analysis per EPA protocol. Details of this analysis as well as the overall sampling program results are described in Section V of this document.

Waste Treatment Equipment Manufacturers - Various manufacturers of waste treatment equipment were contacted by phone or visited to determine cost and performance data on specific technologies. Information collected was based both on manufacturer's research as well as on in-situ operation at plants that were often not battery manufacturers but had similar wastewater characteristics (primarily toxic metal wastes).

Utilization of Industry Data

Data collected from the previously described sources are used throughout this report in the development of a base for BPT and BAT limitations, and NSPS and pretreatment standards. Previous EPA studies as well as the literature provided the basis for the initial battery subcategorization discussed in Section IV. This subcategorization was further refined to an anode grouping basis as the result of information obtained from the plant survey and evaluation. Raw wastewater characteristics for each subcategory presented in Section V were obtained from screening and verification sampling because raw waste information from other sources was so fragmented and incomplete as to be unusable. Selection of pollutant parameters for control (Section VI) was based on both dcp responses and plant sampling. These provided information on both the pollutants which plant personnel felt would be in their wastewater discharges and those pollutants specifically found in battery manufacturing wastewaters as the result of sampling. Based on the selection of pollutants requiring control and their levels, applicable treatment technologies were identified and then studied and discussed in Section VII of this document. Actual waste treatment technologies utilized by battery plants (as identified in dcp and seen on plant visits) were also used to identify applicable treatment technologies. The cost of treatment (both individual technologies and systems) based primarily on data from equipment manufacturers is contained in Section VIII of this document. Finally, dcp data and sampling data are utilized in Sections IX, X, XI, XII, and XIII (BPT, BAT, NSPS, Pretreatment, and BCT, respectively) for the selection of applicable treatment systems and the presentation of achievable effluent levels and actual effluent levels obtained for each battery subcatgegory.

INDUSTRY DESCRIPTION

Background

The industry covered by this document makes modular electric power sources where part or all of the fuel is contained within the unit. Electric power is generated directly from a chemical reaction rather than indirectly through a heat cycle engine. Batteries using a radioactive decay source when a chemical reaction is part of the operating system were considered.

Historical – Electrochemical batteries and cells were assembled by Alessandro Volta as early as 1798. His work establishing the relationship between chemical and electrical energy followed by 12 years the discovery of the galvanic cell by Galvani; and by 2000 years the use of devices in the Middle East which from archeological evidence appear to be galvanic cells. Volta used silver and zinc electrodes in salt water for his cells. Soon after Volta's

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experiments, Davy, and then Faraday, used galvanic cells to carry out electrolysis studies. In 1836 Daniell invented the cell bearing his name. He used a copper cathode in copper sulfate solution separated by a porous cup from a solution of zinc sulfate in dilute sulfuric acid which contained the amalgamated zinc anode. In 1860, Plante presented to the French Academy of Sciences the lead acid storage battery he had developed, and in 1868 Leclanche developed the forerunner of the modern dry cell. Leclanche used an amalgamated zinc anode, and a carbon cathode surrounded by manganese dioxide, and immersed both in an ammonium chloride solution. The portable dry cell was developed in the late 1880's by Gassner who prepared a paste electrolyte of zinc oxide, ammonium chloride and water in a zinc can, inserted the carbon rod and manganese dioxide, then sealed the top with plaster of Paris. The cell was produced commercially. Several other acid-electrolyte cells using amalgamated zinc anodes and carbon or platinum cathodes saw limited use prior to 1900.

Lalande and Chaperon developed a caustic soda primary battery about 1880 which was used extensively for railroad signal service. Amalgamated zinc anodes and cupric oxide cathodes were immersed in a solution of sodium hydroxide. A layer of oil on the surface of the electrolyte prevented evaporation of water, and the formation of solid sodium carbonate by reaction of carbon dioxide in the air with the caustic soda electrolyte. Batteries with capacities to 1000 ampere hours were available.

A storage battery of great commercial importance during the first half of this century was the Edison cell. Although the system is not manu-factured today, a large volume of research is being directed toward making it a workable automotive power source. The system consists of iron anodes, potassium hydroxide electrolyte, and nickel hydroxide cathodes. The iron powder was packed in flat "pockets" of nickel-plated steel strips. The nickel hydroxide, with layers of nickel flakes to improve conductivity, was packed in tubes of nickel-plated steel strip. The batteries were rugged and could withstand more extensive charge-discharge cycling than lead acid storage batteries. Their greater cost kept them from replacing lead acid batteries.

Another cell only recently displaced from the commercial market is the Weston cell. For decades the Weston cell, consisting of an amalgamated cadmium anode and a mercurous sulfate cathode in a cadmium sulfate solution, was used as a voltage reference standard in industrial instruments. Introduction of new solid state devices and circuits has displaced the Weston cell from most of its former industrial applications and it is no longer commercially available.

New battery systems are introduced even today. In the past decade implantable lithium batteries have been developed for heart pacemakers, of which tens of thousands are in use. Huge development

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programs have been funded for electric powered automobiles. The liquid sodium-liquid sulfur system is one of the new "exotic" systems being studied. Advancing technology of materials coupled with new applications requirements will result in development of even newer systems as well as the redevelopment of older systems for new applications. Figure III-1 (Page 46), graphically illustrates the amplitude of systems in use or under development in 1975 for rechargeable batteries. This plot of theoretical specific energy versus equivalent weight of reactants clearly shows the reason for present intensive developmental efforts on lithium and sodium batteries, as well as the Edison battery ($Fe/NiOOH$) and the zinc-nickel oxide battery.

<u>Battery Definitions and Terminology</u> - Batteries are named by various systems. Classification systems include end-use, size, shape, anode-cathode couple, inventor's name, electrolyte type, and usage mode. Thus a flashlight battery (end-use), might also be properly referred to as a D-Cell (size), a cylindrical cell (shape), a zinc-manganese dioxide cell (anode-cathode couple), a Leclanche cell (inventor), an acid cell (electrolyte type), and a primary cell (usage mode), depending on the context. In the strictest sense, a cell contains only one anode-cathode pair, whereas a battery is an assemblage of cells connected in series to produce a greater voltage, or in parallel to produce a greater current. Common usage has blurred the distinction between these terms and frequently the term battery is applied to any finished entity sold as a single unit, whether it contains one cell, as do most flashlight batteries, or several cells, as do automobile batteries. In this document the marketed end product is usually referred to as a battery. Manufacturing flow charts and construction diagrams reveal the actual assembly details.

In this document, the terms "battery" and "cell" are used only for self-contained galvanic devices, i.e., those devices which convert chemical energy to electrical energy and which do not require a separate chemical reservoir for operation of the device. Cells in which one of the reacting materials is oxygen supplied by the atmosphere in which the cell operates are included as well as cells which contain all of the reacting chemicals as part of the device. In some literature, reference is made to electrolysis cells or batteries of electrolysis cells. Those devices are for chemical production or metal winning and are not covered by this discussion. Fuel cells, although functioning as galvanic devices, must be supplied with the chemical energy from an external source, and are not considered in this document.

The essential parts of an electrochemical cell designed as a portable source of electrical power are the same regardless of the size of the unit. From the smallest cell used in a watch to the massive storage batteries used in telephone branch exchanges there is an <u>anode</u>, some-

times called the negative plate, a cathode, also called the positive plate, and electrolyte. The anode and cathode are referred to by the general term electrodes. One or both electrodes consist of a support or grid which serves as a mechancial support and current collector, and the active material which actually undergoes electrochemical reaction to produce the current and voltage characteristics of the cell. Sometimes the active material is the electrode structure itself. The combination of an inert current collecting support and active material is an electrode system. For convenience, in this document as well as in many publications, the terms cathode or anode are used to designate the cathode system or the anode system.

Most practical modern batteries contain insulating porous separators between the electrodes. The resulting assembly of electrodes and electrolyte is contained in a protective case, and terminals attached to the cathode and anode are held in place by an insulating material.

The operating characteristics of a battery are described by several different parameters referred to collectively as the battery performance. Voltage and current will vary with the electrical load placed on the battery. In some batteries, the voltage will remain relatively constant as the load is changed because internal resistance and electrode polarization are not large. Polarization is the measure of voltage decrease at an electrode when current density is increased. Current density is the current produced by a specified area of electrode - frequently milliamperes per square centimeter. Thus, the larger the electrode surface the greater the current produced by the cell unit at a given voltage.

Battery power is the instantaneous product of current and voltage. Specific power is the power per unit weight of battery, power density is the power per unit volume. Watts per pound and watts per cubic foot, respectively, are common measures of these performance characteristics. Power delivered by any battery depends on how it is being used, but to maximize the power delivered by a battery the operating voltage must be substantially less than the open-circuit or no-lead voltage. A power curve is sometimes used to characterize battery performance under load, but because the active materials are being consumed, the power curve will change with time. Because batteries are self-contained power supplies, additional ratings of specific energy and energy density must be specified. These are commonly measured in units of watthours per pound and watthours per cubic foot, respectively. These latter measures characterize the total energy available from the battery under specified operating conditions and allow comparison of the ability of different battery systems to meet the requirements of a given application. Figure III-2 (Page 47) illustrates how these measures of

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performance are used to compare battery systems with each other and with alternative power sources.

The suitability of a battery for a given application is determined not only by its voltage and current characteristics, and the available power and energy. In many applications, storage characteristics and the length of time during which a battery may be operational are also important. The temperature dependence of battery performance is also important for some applications. Storage characteristics of batteries are measured by shelf-life and by self-discharge, the rate at which the available stored energy decreases over time. Self-discharge is generally measured in percent per unit time and is usually dependent on temperature. In some battery types, self-discharge differs during storage and use of the battery. For rechargeable cells, cycle-life, the number of times a battery may be recharged before failure, is often an important parameter.

Battery Applications and Requirements - Batteries are used in so many places that it would be impractical to try to name all of them. Each application presents a unique set of battery performance requirements which may place primary emphasis on any specific performance parameter or combination of parameters. The applications may usefully be considered, however, in groups for which the general purpose and primary performance requirements are similar. Such groups are shown in Table III-2.

Table III-2

Purpose	Application
1. Portable electric power	flashlights, toys, pocket calculators
2. Electric power storage	automobile batteries, solar powered electrical systems
3. Standby or emergency electrical power	emergency lighting for hallways and stairways, life raft radio beacons
4. Remote location electrical power	spacecraft, meteorological stations, railway signals
5. Voltage leveling	telephone exchanges and PBX's
6. Secondary voltage standard	regulated power supplies

The requirements for a flashlight battery are: low cost, long shelf life, intermittent use, moderate operating life. The household user expects to purchase replacement cells at low cost after a reasonable operating life, but does expect long periods before use or between uses.

An automobile battery must be rechargeable, produce large currents to start an engine, operate both on charge and discharge over a wide temperature range, have long life, and be relatively inexpensive when replacement is necessary. The user looks for high power density, rechargeability, and low cost.

Standby lighting, and life raft emergency radio beacons represent two similar applications. For standby lighting power in stairways and halls, the battery is usually a storage battery maintained in a constant state of readiness by the electrical power system and is activated by failure of that primary system. Such a battery system can be activated and then restored to its original state many times and hence can be more expensive and can have complex associated equipment. Weight is no problem, but reliable immediate response, high energy density and power density are important. The emergency radio beacon in a life raft is required to be 100 percent reliable after storage of up to several years. It will not be tested before use, and when activated will be expected to operate continuously until completely discharged. Light weight may be important. Instantaneous response is not a requirement although a short time for activation is expected.

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Remote location operation such as arctic meteorological stations and orbiting spacecraft requires very high reliability and long operating life. Cost is usually of no consequence because overall cost of launching a satellite or travel to a remote location far exceeds any possible battery cost. Rechargeability is required because solar cells (solid state devices producing small electrical power levels directly from solar illumination) can be used to recharge the batteries during sunlight periods to replace the energy used in brief periods of high power demand for transmissions or satellite equipment operation. High power density for meteorological stations and high specific power for satellites is therefore more important than high energy density or high specific energy because the rechargeability requirement means energy can be replaced. Additional requirements are reliable operation over a wider range of temperatures than are usually experienced in temperate earth regions, and sealed operation to prevent electrolyte loss by gassing on charge cycles.

Voltage leveling and voltage standards are similar. Voltage leveling is a requirement for certain telephone systems. The batteries may be maintained in a charged state, but voltage fluctuations must be rapidly damped and some electrochemical systems are ideally suited to this purpose. An additional requirement is the provision of standby power at very stable voltages. Such operation is an electrochemical analogue of a surge tank of a very large area, maintaining a constant liquid head despite many rapid but relatively small inflows and outflows. The use of batteries for secondary voltage standards requires stability of voltage with time and under fluctuating loads. Though similar to the voltage leveling application, the devices or instruments may be portable and are not connected to another electrical system. Frequently power is supplied by one battery type and controlled by a different battery type. Usually cost is a secondary consideration, but not completely ignored. For secondary voltage standards, wide temperature ranges can usually be avoided, but a flat voltage-temperature response is important over the temperature range of application. Power and energy density as well as specific power and energy become secondary considerations also, in both of these applications.

Battery Function and Manufacture

The extremely varied requirements outlined have led to design and production of many types of batteries. Because battery chemistry is the first determiner of performance, practically every known combination of electrode reactions has been studied - at least on paper. Many of the possible electrode combinations are in use in batteries today. Others are being developed to better meet present or projected needs. Some have become obsolete, as noted earlier. Short discussions on electrochemistry of batteries, battery construction and manufacturing are presented to help orient the reader.

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Battery Chemistry - The essential function of the electrodes in a battery is to convert chemical energy into electrical energy and thereby to drive electrical current through an external load. The driving force is measured in volts, the current is measured in amperes. The discrete charges carrying current in the external circuit, or load, are electrons, which bear a negative charge. The driving force is the sum of the electromotive force, or EMF, of the half-cell reactions occurring at the anode and the cathode. The voltage delivered by a cell is characteristic of the overall chemical reaction in the cell. The theoretical open-circuit (no-load) voltage of a cell or battery can be calculated from chemical thermodynamic data developed from non-electrochemical experiments. The cell voltage is related to the Gibbs free energy of the overall chemical reaction by an equation called the Nernst equation. The variable factors are temperature and concentration of the reactants and products.

Voltages (or more properly the EMF) of single electrode reactions are often used in comparing anodes of cathodes of different types of cells. These single electrode (or half-cell) voltages are actually the voltages of complete cells in which one electrode is the standard hydrogen electrode which has an arbitrarily assigned value of zero. In all such calculations, equilibrium conditions are assumed.

In this brief discussion, only the net half-cell reactions are discussed. The very complex subject of electrode kinetics, involving a study of exactly which ionic or solid species are present and in what quantities, can be found in any of several electrochemistry textbooks.

The anode supplies electrons to the external circuit - the half-cell reaction is an oxidation. The cathode accepts electrons from the external circuit - the reaction is a reduction. Half-cell reactions can occur in either forward or reverse direction, at least in theory. Some, however, cannot be reversed in a practical cell. Tables III-3 and III-4 show the reactions as they are used in practical cells for delivery of power. In those cells which are rechargeable, charging reverses the direction of the reaction as written in the tables.

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TABLE III-3

ANODE HALF-CELL REACTIONS (electrolyte)

$Cd + 2OH^- \rightleftharpoons Cd(OH)_2 + 2e$ (alkaline)

$Ca \rightleftharpoons Ca^{+2} + 2e$ (nonaqueous inorganic)

$Pb + H_2SO_4 \rightleftharpoons PbSO_4 + 2H^+ + 2e$ (acidic)

$Zn \rightleftharpoons Zn^{+2} + 2e$ (acidic)

$Li \rightleftharpoons Li^+ + e$ (molten salt, organic, nonaqueous inorganic)

$Mg \rightleftharpoons Mg^{+2} + 2e$ (sea water)

$Zn + 2OH^- \rightleftharpoons Zn(OH)_2 + 2e$ (alkaline)
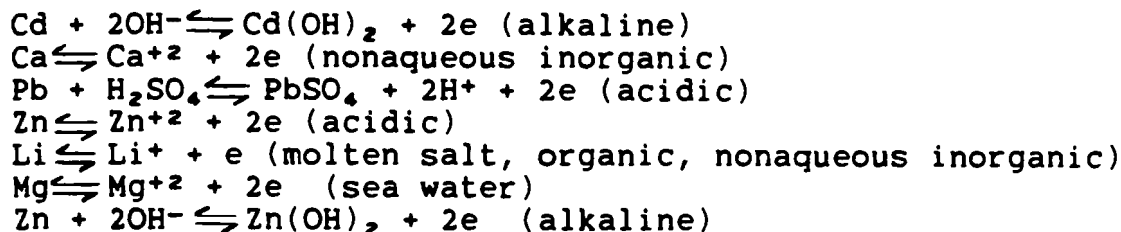
TABLE III-4

CATHODE HALF-CELL REACTIONS (electrolyte)

$e + NiOOH + H_2O \rightleftharpoons Ni(OH)_2 + OH^-$ (alkaline)

$4e + Ag_2O_2 + 2H_2O \rightleftharpoons 2Ag + 4OH^-$ (alkaline)

$2e + Ag_2O + H_2O \rightleftharpoons 2Ag + 2OH^-$ (alkaline)

$2e + HgO + H_2O \rightleftharpoons Hg + 2OH^-$ (alkaline)

$2e + PbO_2 + SO_4^{-2} + 4H^+ \rightleftharpoons PbSO_4 + 2H_2O$ (acid)

$2e + 2MnO_2 + 2NH_4Cl + Zn^{+2} \rightleftharpoons Mn_2O_3 + H_2O + Zn(NH_3)_2Cl_2$ (acid)

$2e + 2AgCl + Zn^{+2} \rightleftharpoons 2Ag + ZnCl_2$ (acid)

$e + TiS_2 + Li^+ \rightleftharpoons TiS_2:Li, e$ (propylene carbonate)

$2e + 2SO_2 \rightleftharpoons S_2O_4^{-2}$ (acetonitrile)

$4e + 2SOCl_2 + 4 Li^+ \rightleftharpoons 4 LiCl + (SO)_2$ (thionyl chloride)

$2e + I_2 + 2 Li^+ \rightleftharpoons 2 LiI$ [poly(2 vinyl)propylene]

$2e + PbI_2 + 2Li^+ \rightleftharpoons 2 LiI + Pb$ (nonaqueous inorganic)

$2e + PbS + 2Li^+ \rightleftharpoons Li_2S + Pb$ (nonaqueous inorganic)

$e + MnO_2 + H_2O \rightleftharpoons MnOOH + OH^-$ (alkaline)

$e + MnOOH + H_2O \rightleftharpoons Mn(OH)_2 + OH^-$ (alkaline)

$8e + m\text{-}C_6H_4(NO_2)_2 + 6NH_4^+ + Mg^{+2} \rightleftharpoons m\text{-bis-}C_6H_4(NHOH)_2 + 6NH_3 + Mg(OH)_2$ (ammonia)

$2e + PbCl_2 \rightleftharpoons Pb + 2Cl^-$ (sea water)

$e + CuCl \rightleftharpoons Cu + Cl^-$ (sea water)

$e + AgCl \rightleftharpoons Ag + Cl^-$ (sea water)

$4e + O_2 + 2H_2O \rightleftharpoons 4OH^-$ (alkaline)

Most presently produced battery systems are based on aqueous electrolytes. However, lithium and thermal batteries, and at least one magnesium cell have non-aqueous electrolyte. Because lithium reacts vigorously with water, organic or non-aqueous inorganic electrolytes are usually, but not always, used with this very high energy anode metal. Thermal batteries are made with the electrolyte in a solid form and are activated by melting the electrolyte with a pyrotecnic device just prior to use. One type of magnesium reserve cell uses a liquid ammonia electrolyte which is injected under pressure just prior to use.

In aqueous systems, any of the anode reactions can be coupled with any of the cathode reactions to make a working cell, providing the electrolytes are matched and the overall cell reaction can be balanced at electrical neutrality. As examples:

Leclanche:
anode: $Zn \rightleftharpoons Zn^{+2} + 2e$ (acid)
cathode: $2e + 2MnO_2 + 2NH_4Cl + Zn^{+2} \rightleftharpoons Mn_2O_3 + H_2O + Zn(NH_3)_2Cl_2$ (acid)
cell: $Zn + 2MnO_2 + 2NH_4Cl \rightleftharpoons Mn_2O_3 + H_2O + Zn(NH_3)_2Cl_2$

Alkaline Manganese:
anode: $Zn + 2OH^- \rightleftharpoons Zn(OH)_2 + 2e$ (alkaline)
cathode: $e + MnO_2 + H_2O \rightleftharpoons MnOOH + OH^-$ (alkaline)
          $e + MnOOH^- + H_2O \rightleftharpoons Mn(OH)_2 + OH^-$ (alkaline)
cell: $Zn + MnO_2 + 2H_2O \rightleftharpoons Zn(OH)_2 + Mn(OH)_2$

One essential feature of an electrochemical cell is that all conduction within the electrolyte must be ionic. In aqueous electrolytes the conductive ion may be H^+ or OH^-. In some cases metal ions carry some of the current. Any electronic conduction between the electrodes inside the cells constitutes a short circuit. The driving force established between the dissimilar electrodes will be dissipated in an unusable form through an internal short circuit. For this reason, a great amount of engineering and design effort is applied to prevention of formation of possible electronic conduction paths and at the same time to achieving low internal resistance to minimize heating and power loss.

Close spacing of electrodes and porous electrode separators lead to low internal electrolyte resistance. But if the separator deteriorates in the chemical environment, or breaks under mechanical shock, it may permit electrode-electrode contact resulting in cell destruction. Likewise, in rechargeable cells, where high rates of charging lead to rough deposits of the anode metal, a porous separator may be penetrated by metal "trees" or dendrites, causing a short circuit. The chemical compatability of separators and electrolytes is an important factor in battery design.

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Long shelf life is frequently a requirement for batteries. Shelf life is limited both by deterioration of battery separators and by corrosion (self-discharge) of electrodes which decreases the available electrical energy and may also result in other types of cell failure. As an example, corrosion of the zinc anode in Leclanche cells may result in perforation of the anode and leakage of electrolyte. Compatability of the active material of the electrodes in contact with the electrolyte to minimize these self-discharge reactions is an electrochemical engineering problem. Two of the approaches to this problem are outlined here.

Some applications require only one-time use, and the electrolyte is injected into the cell just before use, thereby avoiding long time contact of electrode with electrolyte. The result is a reserve battery. One reserve battery design (now abandoned) used a solid electrolyte and the battery was constructed in two parts which were pressed together to activate it. The parts could be separated to deactivate the battery. Up to twenty-five cycles of activation-deactivation were reported to be possible. Reserve batteries are usually found in critical applications where high reliability after uncertain storage time justifies the extra expense of the device.

In other applications, long shelf life in the activated state is required. This allows repeated intermittent use of the battery, but is achieved at the price of somewhat lower certainty of operation than is provided by reserve cells. Special fabrication methods and materials then must be used to avoid self-discharge by corrosion of the anode. In Leclanche cells, the zinc is protected from the acid electrolyte by amalgamating it; in some magnesium cells a chemical reaction with the electrolyte forms a protective film which is subsequently disrupted when current is drained; in some lithium bat-teries, the very thin film formed by chemical reaction with electrolyte conducts lithium ions at a rate sufficiently high to be usable for power delivery. All three types of cells require the use of specific chemicals and special assembly techniques.

Operation of cells in the rechargeable mode places additional constraints on the chemical components and construction materials. In aqueous-electrolyte cells, vented operation may be possible, as with lead acid automotive and nickel cadmium batteries. Or, the cells may be sealed because remote operation prevents servicing and water replacement. Cells with liquid organic or inorganic electrolyte also are sealed to prevent escape of noxious vapors. Organic liquids used in cells manufactured in the U. S. today include: methyl formate, acetonitrile, methyl acetate, and dioxolane. Inorganic liquids include thionyl chloride and ammonia.

Sealed operation of rechargable cells introduces two major problems relating to pressure buildup that must be accommodated by design and

materials. Pressure changes normally occur during discharge-charge cycling and must be accomodated by the battery case and seal designs. Many applications also require cells to accept overcharging. In nickel-cadmium cells the oxygen or hydrogen pressure would build to explosive levels in a short time on overcharge. As a result cells are designed with excess uncharged negative material so that when the nickel electrode is completely charged the cadmium electrode will continue to charge, and oxygen evolved at the nickel electrode will migrate under pressure to the cadmium and be reduced before hydrogen evolution occurs. A steady state is reached where continuous overcharge produces no harmful effects from pressure and no net change in the composition of electrodes or electrolytes. The excess uncharged negative material ensures that hydrogen is not evolved. Oxygen recombination is used because the alternative reaction of hydrogen recombination at an excess uncharged positive electrode proceeds at very low rates unless expensive special catalysts are present.

Cell reversal is the other operational phenomenon requiring chemical and electrochemical compensation. Cell reversal occurs when a battery of cells is discharged to a point that one cell in the battery has delivered all of its capacity (i.e., the active material in at least one electrode is used up) but other cells are still delivering power. The current then travels through the depleted cell in the same direction but the cell becomes an electrolytic cell.

In a nickel-cadmium battery, cell reversal results in hydrogen generation at the nickel electrode or oxygen generation at the cadmium electrode. Cells can be designed to avoid pressure build-up in those instances where reversal may occur. One method is the incorporation of an antipolar mass (APM) in the nickel electrode. The APM is $Cd(OH)_2$. When cell reversal occurs, the APM is reduced to cadmium metal. However, by using the proper amount of APM, oxygen generated at the cell anode builds to sufficient pressure to react with the metallic cadmium in the APM before all of the $Cd(OH)_2$ is reduced. Thus, the oxygen generation-reduction cycle discussed above is established and hydrogen evolution is avoided. For the oxygen cycle to function for either overcharge or cell reversal the separator must be permeable to oxygen in nickel cadmium batteries. All sealed cells also have an overpressure release to prevent violent explosions.

Special applications may require special operating conditions. The ability of a cell to perform its function of delivering current is determined first of all by the kinetics of the electrode processes for the anode-electrolyte-cathode system chosen. For a given electrode combination, the current per unit area of active surface is characteristic of the system. Temperature and pressure have an effect on the fundamental electrode kinetics, but only in special applications is it possible to design a battery for operation at other

than ambient temperature. For some high-power drain applications such as prime mover power plants and central station power it is feasable to build a high-temperature system to take advantage of the improved electrode kinetics and reduced electrolyte resistance. Of course the kinetics of corrosion processes are also enhanced, so additional materials problems must be overcome.

For the majority of cells which must be operated at a temperature determined by the environment, the only practical way to achieve greater power outputs is to increase the active surface area of the electrodes. The usual approach to increasing surface area is to subdivide the electrode material. Powdered or granular active material is formed into an electrode with or without a structural support. The latter may also function as a current collector.

The limitation to increasing the surface area is the fact that a mass of finely divided active material immersed in electrolyte will tend to lose surface area with time, a phenomenon similar to Ostwald ripening of silver halide photograph emulsion. The smaller particles, which provide the large surface area, dissolve in the electrolyte and the larger particles grow even larger. The nature of the electrolyte and active mass is the main determinant of the extent of this phenomenon.

A further limitation to the power drain available from porous electrodes results from a phenomenon called concentration polarization. Total ampere-hours available is not affected by this process, but the energy delivered is limited. In a thick porous body such as a tube or pocket type electrode, the electrolyte within the narrow, deep pores of the electrode can become overloaded with ionic products of electrode reaction or depleated of ions required for electrode reaction. For instance, at the negative plate of a lead-acid battery sulfate ions are required for the reaction:

$$Pb + SO_4 \rightleftharpoons PbSO_4 + 2e$$
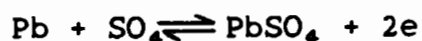
When an automotive battery is fully charged the concentration of sulfuric acid, hence sulfate ions, is very high. Large currents can be sustained for sufficient time to crank a cold engine until it starts. However, when the battery is "low", i.e. the sulfate ion concentration throughout the battery is low, sufficient sulfate ions are initially present in the pores of the negative plate to sustain the negative plate reaction for a brief period of cranking the engine, then the sulfate is so drastically depleted that the cranking current cannot be sustained. If the battery is allowed to "rest" a few minutes, the rather slow process of diffusion will replenish sulfate ions in the interior of the pores and in effect return to effective use that "deep" surface area. The battery appears to come to "life" again. Cranking currents will again deplete the supply of ions and the battery is "dead." If a "light" load, such as a radio is placed on

the nearly "dead" battery the diffusion process may be able to supply sufficient ions on a continuing basis so that the battery appears to be functioning normally.

The above example is familiar to many people. Similar phenomena occur in any battery with porous electrodes. In some primary batteries the discharge products may increase in concentration to a point of insolubility and permanently block off active material surface. Thus a battery may deliver significantly fewer ampere-hours to a predetermined cut-off voltage when used at the C/2 ampere rate than at the C/20 ampere rate where C is the theoretical ampere-hour capacity of the battery and the numerical denominator is in hours.

Concentration polarization also limits the rate at which rechargeable batteries can be charged. Use of higher charging voltages to shorten the recharge time can result in gassing (e.g., production of hydrogen or oxygen in aqueous electrolyte cells) because the electrolyte constituents required for charging become depleted in the vicinity of the electrode and a different, unwanted reaction begins to carry the current. This is an inefficient mode of operation. In rechargeable cells there is an additional consideration in preparing porous electrodes. The surface area of the electrodes must be substantially the same after recharge as it was after the initial formation charging. It is of little benefit to provide large surface area in the manufacture of the cell if it cannot be sustained during a usable number of cycles.

The steps used to manufacture batteries with stable, large-surface-area electrodes are outlined for several types of batteries to show similarities and differences in methods. Further details of techniques for each specific battery type are given in Section V.

Battery Manufacture – The details of battery construction vary with the type of battery. For the usual liquid electrolyte batteries the steps are: manufacture of structural components, preparation of electrodes, and assembly into cells. Fabrication of the structural components – cell cases or caps, terminal fittings or fixtures, electrode support grids, separators, seals, and covers – are all manufacturing processes not directly involving the electrochemistry of the cell. These components may be fabricated by the battery producer, or they may be supplied by other manufacturers. The steps considered to be battery manufacturing operations are: anode and cathode fabrication, and ancillary operations (all operations not primarily associated with anode and cathode manufacture, or structural component fabrication).

Discussion of the manufacturing operations is divided into three parts – anodes, cathodes, and ancillary operations. In each part, specific

operations are illustrated by reference to particular battery types. Ten battery types were chosen to illustrate a range of materials, applications, and sizes. Figures III-3 through III-12 (Pages 48-57) are drawings or cutaway views of these ten batteries. Figures III-13 through III-20 (Pages 58-65) are simplified manufacturing process flow diagrams for these same batteries. Reference to the figures should help to understand the discussion.

Anodes

Anodes are prepared by at least four basic methods depending on the strength of the material and the application, i.e., high current drain or low current drain. Once the electrodes are fabricated they may require a further step, formation, to render them active. As noted earlier, anodes are metals when they are in their final or fully charged form in a battery. Some anodes such as lithium anodes, and zinc anodes for some Leclanche cells, are made directly by cutting and drawing or stamping the pure metal sheet. Lithium, because of its flexibility, is either alloyed with a metal such as aluminum, or is attached to a grid of nickel or other rigid metal. Drawn sheet zinc anodes are rigid enough to serve as a cell container.

Zinc anodes for some alkaline-manganese batteries are made from a mixture of zinc powder, mercury, and potassium hydroxide. Zinc is amalgamated to prevent hydrogen evolution and thus, corrosion at the anode.

Anodes for most lead-acid batteries and some nickel-cadmium cells are prepared from a paste of a compound of the anode metal (lead oxides) or cadmium hydroxide, respectively. Additives may be mixed in, then the paste is applied to a support structure and dried.

The techniques for preparing the compounds of the anode metal may be unique to the battery manufacturing process. For pocket-type nickel cadmium batteries, cadmium metal is oxidized in a high temperature air stream, then hydrated to cadmium hydroxide. Graphite, to increase conductivity, and iron oxide, to keep the cadmium in a porous state during cycling, may be mixed into the cadmium hydroxide.

Organic expanders, lampblack, and barium sulfate are added to the paste mixture for lead-acid battery anodes. The expanders maintain the lead in a porous state during charge-discharge cycling. The organic expanders coat the lead particles, preventing agglomeration. Barium sulfate holds the lead grains apart. Lampblack aids in the formation step.

In addition to physically applying the active material to the support structure as a metal or compound, some anode active materials are prepared from soluble metal compounds. High-rate nickel-cadmium

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battery anodes are prepared by impregnating a porous nickel plaque with a solution of cadmium nitrate. The plaque is transferred to an alkali solution or is made the cathode of an electrolysis cell. Either technique precipitates the cadmium as the hydroxide which is subsequently converted to metallic cadmium in the forming step.

To sum up, the active mass for anodes is usually prepared as the massive metal, finely divided metal, finely divided metal compound, or as a soluble salt of the metal which is precipitated onto a carrier or support structure. In most batteries, there is an additional support structure, such as the paste for the negative active mass of a lead-acid battery which is pressed into a grid of lead or a lead alloy. Different types of nickel-cadmium batteries exemplify three approaches to fabrication of anodes. As noted above, the cadmium for pocket type anodes is admixed with other materials then loaded into the pockets of a perforated nickel or steel sheet. The method of precipitating an insoluble cadmium compound from a solution of a soluble cadmium salt in the pores of a porous powder metallurgical nickel plaque was also described. For some cells, highly porous cadmium powder is mixed with cadmium compounds and pasted onto a support structure. Chemical production of anode active materials which are specifically used for batteries, are considered as part of battery manufacturing. This process is usually considered as an ancillary operation.

The final step in anode preparation for many types of batteries is formation, or charging, of the active mass. The term "formation" was first used to describe the process by which Plante plates were prepared for lead-acid batteries. In that process, lead sheet or another form of pure lead was placed in sulfuric acid and made anodic, generating a surface layer of lead sulfate, then cathodic, reducing that layer to lead which remained in the finely divided state. Repeated cycling generated a deep layer of finely divided lead for the anodes. Few lead-acid anodes are made that way today, but the term "formation" has remained to designate the final electrochemical steps in preparation of electrodes for any type of battery.

Formation may be carried out on individual electrodes or on pairs of electrodes in a tank of suitable electrolyte, e.g. sulfuric acid for lead-acid battery plates, or potassium hydroxide for nickel-cadmium battery electrodes. Formation of anodes by themselves requires an inert, gassing, counter-electrode. More often the electrodes for a battery are formed in pairs. The cathodes are arranged in the tank in opposition to the anodes or are interspaced between the anodes. Frequently, electrodes are formed in the cell or battery after final assembly. However the electrodes are arranged physically, current is passed through the electrodes to charge them. For some battery types, charge-discharge cycling up to seven times is used to form the electrode.

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Primary battery anodes are almost always prepared in the active form, and require no formation step. Rechargeable battery anodes almost always go through a formation step.

Cathodes

Cathode active materials are never metals despite the common usage of the metal type to designate the cathode active material. "Nickel" cathodes are actually nickel hydroxide, "mercury" cathodes, are actually mercury oxide; "manganese" cathodes (alkaline-manganese battery) are manganese oxide (pyrolusite). Non-metals such as iodine (lithium-iodine battery) and meta-dinitrobenzene (magnesium-ammonia reserve battery) are the other kinds of cathode active materials used. Manufacturing of cathodes for batteries is not necessarily more complex than that of the anodes, however, cathode production encompasses a broader variety of raw materials for use in different battery types.

Cathode active materials are weak electronic conductors at best, and usually possess slight mechanical strength. Therefore, most cathodes must have a metallic current conducting support structure. In addition, a conducting material is frequently incorporated into the active mass. Structural reinforcement may be in the form of a wire mesh, a perforated metal tube, or inert fibrous material, woven or felted. Conducting materials added to the cathode active mass are almost invariably carbon or nickel.

Preparation of the cathode active material in the battery plant is usually restricted to the metal oxides or hydroxides. Cathode active materials for two of the ten battery types discussed here, nickel hydroxide, and leady oxide are specific to battery manufacturing and are usually produced in the battery plant. Cathode active materials for the other types are usually purchased directly from chemical suppliers. For nickel-cadmium pressed powder (pocket-electrode) cells nickel hydroxide is produced by dissolution of nickel powder in sulfuric acid. The nickel sulfate solution is reacted with sodium hydroxide. The resulting nickel hydroxide is centrifuged, mixed with some graphite, spray dried, compacted and mixed with additional graphite. For high-rate cells, nickel oxide is precipitated in the pores of a nickel plaque immersed in nickel nitrate. A process analogous to those described for preparation of high-rate cadmium anodes is used. Lead-acid batteries require a specific oxidation state of lead oxide (24-30 percent free lead) referred to by industry as "leady oxide", which is produced by the ball mill or Barton process. This leady oxide is used for both the anode and the cathode. Chemical production of cathode active materials which are used specifically for batteries are considered part of battery manufacturing usually as an ancillary operation.

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Manganese dioxide for Leclanche cells and alkaline-manganese cells is mixed with graphite to increase conductivity. For Leclanche cells, the mixture may be compacted around the carbon cathode rod, or is poured into the cell as a loose powder and compacted as the carbon rod is inserted. For alkaline-manganese cells, analagous procedures are used except that the cathode active material takes the shape of a cylinder against the wall of the nickel-plated steel can and no carbon rod is used. In the foliar-cell Leclanche battery the manganese dioxide is printed onto a conducting plastic sheet. The other side of the sheet bears the zinc anode film to produce a bipolar electrode. (Bipolar electrodes perform the same function as an anode and cathode of two separate cells connected in series).

The magnesium-ammonia reserve battery uses a different type of cathode structure. A glass fiber pad containing the meta-dinitrobenzene (m-DNB), carbon, and ammonium thiocyanate is placed against a stainless steel cathode current collector. Activation of the battery causes liquid ammonia to flood the cell space, saturate the pad, and dissolve the dry acidic salt (ammonium thiocyanate) and the cathode active material (m-DNB). The m-DNB functions as a dissolved cathodic depolarizer.

The cathode active material for the carbon-zinc (air) cell is oxygen from the air. Therefore, the principal function of the cathode structure is to provide a large area of conductive carbon surface in the immediate vicinity of the electrolyte-air contact region. Air must have free access through the exposed pores of the rigid structure. Electrolyte in the wetted surface pores must have a continuous path to the body of the electrolyte to provide the ionic conduction to the anode. The porous carbon body is wetproofed on the electrolyte surface to prevent deep penetration and saturation or flooding of the pores by electrolyte.

The mercury-zinc cell uses a compacted cathode active material. Mercuric oxide, mixed with graphite is pressed into pellets for use in miniature cells, or is pressed directly into the cell case.

In sum, cathode fabrication almost always includes a rigid, current-carrying structure to support the active material. The active material may be applied to the support as a paste, deposited in a porous structure by precipitation from a solution, fixed to the support as a compacted pellet, or may be dissolved in an electrolyte which has been immobilized in a porous inert structure.

The formation step for cathodes of rechargeable batteries is much the same as that for anodes. Nickel cathodes may be formed outside or inside the assembled cell, in a potassium hydroxide electrolyte. Lead cathodes for lead-acid batteries are handled in a manner similar to that used to make anodes, except they remain in the lead peroxide

state after forming. For some cell types, chemical processes rather than electrolysis are used to form nickel hydroxide and silver oxide cathodes or reactive materials prior to physical application to the electrode support.

Ancillary Operations

Ancillary operations are all those operations unique to the battery manufacturing point source category which are not included specifically under anode or cathode fabrication. They are operations associated mainly with cell assembly and battery assembly. Also chemical production for anode or cathode active materials used only for batteries (discussed above) are considered as ancillary operations.

Cell assembly is done in several ways. The electrodes for rectangular nickel cadmium batteries are placed in a stack with a layer of separator material between each electrode pair and inserted into the battery case. Almost all lead-acid batteries are assembled in a case of hard rubber or plastic with a porous separator between electrode pairs. The cells or batteries are filled with electrolyte after assembly.

Cylindrical cells of the Leclanche or the alkaline-manganese type are usually assembled by insertion of the individual components into the container. For Leclanche batteries, a paper liner which may be impregnated with a mercury salt is inserted in the zinc can, then depolarizer mixture, a carbon rod, and electrolyte are added. The cell is closed and sealed, tested, aged, and tested again. Batteries are assembled from cylindrical cells to produce higher voltages. Several round cells can be placed in one battery container and series connections are made internally. Two terminals are added and the batteries are sealed.

Miniature button cells of the alkaline-manganese and mercury-zinc types are assembled from pellets of the electrode active mass plus separator discs, or the electrodes may be pressed directly in the cell case to assure electrical contact and to facilitate handling during assembly.

Leclanche foliar cell batteries are a specialty product which illustrate the possibility of drastically modifying the conventional battery configuration when a need exists. The bipolar electrodes and separators are heat sealed at the edges. After each separator is sealed in place, electrolyte is applied to it before the next electrode is sealed in place. When the battery is completed the entire assembly is sandwiched between two thin steel sheets. Assembly is completely automated. The resulting six-volt battery is about

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three inches by four inches by three-sixteenths of an inch thick and has high specific power and power density, but short life.

A contrasting battery is the carbon-zinc (air) cell. The cast amalgamated zinc anodes positioned on each side of a porous carbon air electrode are attached to the cover of the cell. Dry potassium hydroxide and lime are placed in the bottom of the cell case, the cover is put in place and sealed, and a bag of dessicant is placed in the filler opening. The cell is shipped dry and the user adds water to activate it. This cell has a very low power density but a very long operating life.

Ancillary operations for this document, beside specific chemical production, include some dry operations as well as cell washing, battery washing, the washing of equipment, floors and operating personnel. Because the degree of automation varies from plant to plant for a given battery type, the specific method of carrying out the ancillary operations is not as closely identifiable with a battery type as are the anode and cathode fabrication operations.

INDUSTRY SUMMARY

The battery manufacturing industry in the United States includes 230 active facilities operated by 132 different companies. In all, the industry produced approximately 1.8 million tons of batteries valued at 2.1 billion dollars in 1976, and employed over thirty-three thousand workers. As Figure III-21 (Page 66) shows, both the value of industry products, and the number of employees has increased significantly in recent years. This growth has been accompanied by major shifts in battery applications, and the emergence of new types of cells and decline and phasing out of other cell types as commercially significant products. Present research activity in battery technology and continuing changes in electronics and transportation make it probable that rapid changes in battery manufacture will continue. The rapid changes in battery manufacturers is reflected in the age of battery manufacturing plants. Although a few plants are more than 60 years old, battery manufacturing facilities are fairly new with over half reported to have been built in the past twenty years. Most have been modified even more recently.

Plants commonly manufacture a variety of cells and batteries differing in size, shape, and performance characteristics. Further, a signficant number of plants produce cells using different reactive couples but with a common anode material, (e.g. mercury-zinc and alkaline manganese batteries both use a zinc anode). Thirteen facilities currently produce cells or batteries using two or more different anode materials and therefore are considered in two or more subcategories. Some battery manufacturing facilities purchase finished cell components and assemble the final battery products without performing some of the whole range of manufacturing process

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steps on-site. Other facilities only manufacture battery components, and perform battery manufacturing process operations without producing finished batteries. Finally, some battery plants have fully integrated on-site production operations including metal forming and inorganic chemicals manufacture which are not specific to battery manufacturing.

The reactive materials in most modern batteries include one or more of the toxic metals: cadmium, lead, mercury, nickel, and zinc. Cadmium and zinc are used as anode materials in a variety of cells, and lead is used in both cathode and anode in the familiar lead-acid storage battery. Mercuric oxide is used as the cathode reactant in mercury-zinc batteries, and mercury is also widely used to amalgamate the zinc anode to reduce corrosion and self discharge of the cell. Nickel hydroxide is the cathode reactant in rechargeable nickel cadmium cells, and nickel or nickel plated steel may also serve as a support for other reactive materials. As a result of this widespread use, these toxic metals are found in wastewater discharges and solid wastes from almost all battery plants. Estimated total annual consumption of these materials in battery manufacture is shown in Table III-5. Since only lead-acid batteries are reclaimed on a significant scale, essentially all of the cadmium, mercury, nickel, and zinc consumed in battery manufacture will eventually be found in liquid or solid wastes either from battery manufacturers or from battery users.

Water is used in battery manufacturing plants in preparing reactive materials and electrolytes, in depositing reactive materials on supporting electrode structures, in charging electrodes and removing impurities, and in washing finished cells, production equipment and manufacturing areas. Volumes of discharge and patterns of water use as well as the scale of production operations, wastewater pollutants, and prevalent treatment practices vary widely among different battery types, but show significant similarities among batteries employing a common anode reactant and electrolyte. Figure III-22 (Page 67) and subsequent discussion summarizes separately the characteristics of plants manufacturing batteries in each of the groups based on anode and electrolyte.

Table III-5

Consumption of Toxic Metals in Battery Manufacture*

METAL	ANNUAL CONSUMPTION	
	Metric Tons	Tons
Cadmium	730	800
Lead	980,000	1,080,000
Mercury	670	740
Nickel	1,200	1,300
Zinc	27,000	29,000

* Based on 1976 data provided in dcp's. Numbers shown are sums of provided data. Because response to raw materials question is incomplete, actual consumption will be higher by 10-20 percent.

Cadmium Subcategory

Cadmium anode cells presently manufactured are based on nickel-cadmium, silver-cadmium and mercury-cadmium couples. Nickel-cadmium batteries are among the most widely used rechargeable cells finding applications in calculators, radios and numerous other portable electronic devices in addition to a variety of industrial applications. Total annual shipments of nickel-cadmium batteries were valued at over one-hundred million dollars in 1977. Silver-cadmium battery manufacture is limited in terms of product weight amounting to less than one percent of the amount of nickel-cadmium batteries manufactured. Small quantities of mercury-cadmium batteries are manufactured for military and industrial applications. Presently ten plants are manufacturing batteries in the cadmium subcategory. Total annual production is estimated to be 5200 metric tons (5750 tons) of batteries with three plants producing over 453.5 metric tons (500 tons) of batteries, and one producing less than .907 metric tons (1 ton) of batteries. Plants vary in size and in number of employees. Total subcategory employment is estimated to be 2500.

Process wastewater flows from this subcategory are variable and total 114,000 l/hr (30,100 gal/hr). Most plants have flows of <18,925 l/hr (<5,000 gal/hr), while two plants have zero process wastewater flows. Normalized process wastewater flows based on the total weight of cadmium anode cells produced varies from 0 to 782 l/kg (94 gal/lb) and averages 148 l/kg (18 gal/lb), with the subcategory having a median flow of 49 l/kg (6 gal/lb). The substantial variations shown in wastewater discharges from these plants reflects major manufacturing process variations, especially between batteries using pressed or pasted electrodes and sintered electrodes. These are addressed in detail in Section V. The most significant usage of process water in cadmium anode battery manufacture is in the deposition of electrode active materials on supporting substrates and in subsequent electrode formation (charging) prior to assembly into cells. These operations

are also major sources of process wastewater. Additional points of process water use and discharge include wet scrubbers, electrolyte preparation, cell wash, floor wash, and employee showers and hand wash intended to remove process chemicals. The most significant pollutants carried by these waste streams are the toxic metals, cadmium, nickel, and silver. The waste streams are predominantly alkaline and frequently contain high levels of suspended solids including metal hydroxide precipitates.

Treatment commonly used included settling or filtration for the removal of solids at all facilities which indicated process wastewater discharge; three plants also indicated the use of coagulants, six pH adjustment, and one chemical precipitation. Two plants indicated the use of material recovery, five plants have sludges contractor hauled, and one plant has sludge landfilled. On-site observation at several plants indicate that the treatment provided is often rudimentary and of limited effectiveness. Battery process wastewater discharges from two cadmium anode battery manufacturing plant flows directly to surface waters, four facilities discharge to municipal sewers, one discharges to both sewers and surface waters, and one plant has zero discharge to navigable waters of the United States. Two facilities have zero battery manufacturing process wastewater discharge. Wastewater treatment provided was not related to the discharge destination.

Cadmium anode batteries are produced in a broad range of sizes and configurations corresponding to varied applications. They range from small cylindrical cells with capacities of less than one ampere-hour to large rectangular batteries for industrial applications with capacities in excess of 100 ampere-hours. In general, batteries manufactured in the smaller cell sizes are sealed while the larger units are of "open" or vented construction.

Manufacturing processes vary in accordance with these product variations and among different facilities producing similar products. Raw materials vary accordingly. All manufacturers use cadmium or cadmium salts (generally nitrate or oxide) to produce cell anodes, and nickel, silver, mercury or their salts to produce cell cathodes. The specific materials chosen depend on details of the process as discussed in Section V. Generally supporting materials are also used in manufacturing the electrodes to provide mechanical strength and conductivity. Raw materials for the electrode support structures commonly include nickel powder and nickel or nickel plated steel screen. Additional raw materials include nylon, polypropylene and other materials used in cell separators, sodium and potassium hydroxide used as process chemicals and in the cell electrolyte, cobalt salts added to some electrodes, and a variety of cell case, seal, cover and connector materials.

Calcium Subcategory

All calcium anode batteries presently produced are thermal batteries for military and atomic applications. Three plants presently manufacture these batteries to comply with a variety of military specifications, and total production volume is limited. The total production of thermal batteries by these facilities was not determined since one plant which produced no process wastewater reported that thermal cell production data were not available. The other two facilities, however, showed total thermal battery production amounting to less than 23 metric tons (25 tons). Total employment for the three facilities manufacturing in the calcium subcategory is estimated to be 240.

Process water use and discharge in this subcategory are limited. Wastewater discharge is reported from only one process operation which is involved in producing the reactive material used to heat the cell for activation. The cell anode, cathode, and electrolyte are all handled in dry processes from which no wastewater discharges are reported. The reported volume of process wastewater discharge from calcium anode cell manufacture varies between 0 and 37.9 l/hr. (10 gal/hr). In terms of the weight of thermal batteries produced the flow varies from 0 to 2.5 l/kg (0.67 gal/lb). The most significant pollutant found in these waste streams is hexavalent chromium which is present primarily in the form of barium chromate. Another pollutant found in these wastewaters is asbestos. Wastewater treatment presently provided is limited to settling for removal of suspended solids (including $BaCrO_4$). One plant reports that sludge wastes are contractor hauled.

Lead Subcategory

The lead subcategory, encompassing lead acid reserve cells and the more familiar lead acid storage batteries, is the largest subcategory both in terms of number of plants and volume of production. It also contains the largest plants and produces a much larger total volume of wastewater.

The lead group includes 184 battery manufacturing facilities of which some 144 manufacture electrodes from basic raw materials, and almost 40 purchase electrodes prepared off-site and assemble them into batteries (and are therefore termed assemblers). Most facilities which manufacture electrodes also assemble them into batteries. In 1976, plants in the lead group ranged in annual production from 10.5 metric tons (11.5 tons) to over 40,000 metric tons (44,000 tons) of batteries with the average production being 10,000 metric tons (11,000 tons) per year. Total annual battery production is estimated to be 1.3 million kkg (1.43 million tons) of batteries. Seven companies owned or operated 42 percent of the plants in this subcategory, consumed over

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793,650 metric tons (875,000 tons) of pure lead and produced over 1.1 million metric tons (1.2 million tons) of batteries. In 1977, total lead subcategory product shipments were valued at about 1.7 billion dollars. The number of employees reported by plants in the lead subcategory ranged from 1 to 643 with total employment estimated to be 18745. Most of the plants employing fewer than 10 employees were found to be battery assemblers who purchased charged or uncharged plates produced in other facilities. The distribution of plants in the lead subcategory in terms of production and number of employees is shown in Figures III-23 and III-24 (Page 68 and 69).

With the exception of lead-acid reserve batteries which are manufactured at only one site, all products in this subcategory are manufactured using similar materials and employ the same basic cell chemistry. Products differ significantly in configuration and in manufacturing processes, however, depending on end use. Lead-acid battery products include cells with immobilized electrolytes used for portable hand tools, lanterns, etc., conventional rectangular batteries used for automotive starting, lighting and ignition (SLI) applications, sealed batteries for SLI use, and a wide variety of batteries designed for industrial applications.

Manufacturers of SLI and industrial lead acid batteries have commonly referred to batteries shipped with electrolyte as "wet-charged" batteries and those shipped without electrolyte as "dry-charged" batteries. The term "dry-charged" batteries which is used to mean any battery shipped without electrolyte includes both damp-charged batteries (damp batteries) and dehydrated plate batteries (dehydrated batteries). Dehydrated batteries usually are manufactured by charging of the electrodes in open tanks (open formation), followed by rinsing and dehydration prior to assembly in the battery case. Damp batteries are usually manufactured by charging the electrodes in the battery case after assembly (closed formation), and emptying the electrolyte before final assembly and shipping. The term "wet-charged" batteries is used to mean any battery shipped with electrolyte. Wet-charged batteries (wet batteries) are usually manufactured by closed formation processes, but can also be produced by open formation processes. Details of these formation process operations are discussed in Section V.

Dehydrated plate batteries afford significantly longer shelf-life than wet batteries or damp batteries. In 1976, sixty plants reported the production of 239,000 metric tons (268,000 tons) of dehydrated plate batteries; over 18 percent of all lead acid batteries produced. Twenty-seven plants reported producing damp batteries which is 9.3 percent of the battery· manufacture total, or 121,000 metric tons (136,000 tons). Contacts with battery manufacturers have indicated a substantial reduction in dehydrated battery manufacture since that

time due largely to the introduction of sealed wet charged batteries using calcium alloy grids which provide improved shelf-life.

Major raw materials for all of these battery types include lead, leady oxide, lead oxide, lead alloys, sulfuric acid, and battery cases, covers, filler caps, separators and other plastic rubber or treated paper components. Generally, additional materials including carbon, barium sulfate, and fibrous materials are added in the manufacture of electrodes. Many manufacturers use epoxy, tar, or other similar materials to seal battery cases, especially in manufacturing industrial batteries. Common alloying elements used in the lead alloys are antimony, calcium, arsenic and tin. Antimony may be used at levels above 7 percent while arsenic, calcium and tin are generally used only in small percentages (1 percent).

Patterns of water usage and wastewater discharge are found to vary significantly among lead battery plants. Variations result both from differences in manufacturing processes and from differences in the degree and type of wastewater control practiced. In general, the major points of process water use are in the preparation and application of electrode active materials, in the "formation" (charging) of the electrodes, and in washing finished batteries. Process wastewater discharges may result from wet scrubbers, floor and equipment wash water and employee showers and hand washes used to remove process materials.

The total volume of discharge from lead subcategory battery plants varies between 0 and 62,000 l/hr (16,400 gal/hr) with a mean discharge rate of 5,800 l/hr (1,532 gal/hr) and a median discharge rate of 3,500 l/hr (925 gal/hr). When normalized on the basis of the total amount of lead used in battery manufacture, these discharge flows vary between 0 and 52.3 l/kg (6.37 gal/lb) with an average of 4.816 l/kg (0.577 gal/lb). Over 60 percent of lead subcategory plants discharge wastewater to POTW. The wastewater from these facilities is characteristically acidic as a result of contamination with sulfuric acid electrolyte and generally contains dissolved lead and suspended particulates which are also likely to contain lead. The prevailing treatment practice is to treat the wastewater with an alkaline reagent to raise its pH, and provide settling to remove particulates and precipitated lead. In-process treatment and reuse of specific waste streams is also common.

Leclanche Subcategory

Plants included in this subcategory manufacture the conventional carbon-zinc Leclanche cell and some silver chloride-zinc and carbon-zinc air cells as well. All of the battery types included have in common the use of an acidic (chloride) electrolyte and use of a zinc anode. Among carbon-zinc air batteries, only "dry" cells which use

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ammonium chloride in the electrolyte are included in this subcategory. Carbon-zinc air depolarized batteries which use alkaline electrolytes are included in the zinc subcategory. The Leclanche subcategory also includes the production of pasted paper separator material containing mercury for use in battery manufacture.

Plants in this subcategory produce a total of over 108,000 metric tons (111,000 tons) of batteries and employ approximately 4,200 persons. Individual plant production ranges from approximately 1.4 metric tons (1.5 tons) to 24,000 metric tons (26,000 tons). In 1977, the total value of product shipments in this subcategory was over 261 million dollars.

A wide variety of cell and battery configurations and sizes are produced in this subcategory including cylindrical cells in sizes from AAA to No. 6, flat cells which are stacked to produce rectangular nine volt transistor batteries, various rectangular lantern batteries, and flat sheet batteries for photographic applications. Only the flat photographic cells are somewhat different in raw material use and production techniques. For specific cell configurations, however, significant differences in manufacturing processes and process wastewater generation are associated with differences in the cell separator chosen (i.e. cooked paste, uncooked paste, pasted paper).

Major raw materials used in the manufacture of batteries in this subcategory include zinc, mercury, carbon, manganese dioxide, ammonium chloride, zinc chloride, silver chloride, paper, starch, flour, and pitch or similar materials for sealing cells. Plastics are also used in producing flat cells for photographic use. The zinc is most often obtained as sheet zinc pre-formed into cans which serve as both cell anode and container although some facilities form and clean the cans on site. For one type of battery, zinc powder is used. The mercury, used to amalgamate the zinc and reduce internal corrosion in the battery, is generally added with the cell electrolyte or separator. It amounts to approximately 1.7 percent by weight of the zinc contained in these cells.

Process water use in this subcategory is limited, and process wastewater production results primarily from cleaning production equipment used in handling cathode and electrolyte materials. Process wastewater is also reported from the production and setting of cooked paste cell separators and from the manufacture of pasted paper separator material.

Estimated total process wastewater flow rates reported by plants in this subcategory range from 0 to 2,158 l/hr (570 gal/hr) with an average of 208 l/hr (55 gal/hr). Eleven facilities reported zero discharge of process wastewater. The maximum reported volume of process wastewater per unit of production (weight of cells produced)

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in this subcategory is 6.4 1/kg (0.76 gal/lb) and the average value is 0.45 1/kg (0.054 gal/lb). All plants reporting process wastewater discharge in this subcategory discharge to municipal treatment systems, except for one plant which discharged 1 gal/day to a dry well. Significant flow rate variations among plants in this subcategory are attributable to manufacturing process differences, to variations in equipment clean-up procedures employed, and the degree of water conservation practiced at each plant.

The most significant pollutants in waste streams from plants in this subcategory are mercury and zinc, ammonium chloride, particulate manganese dioxide and carbon, and starch and flour (used in separator manufacture). Treatment technologies applied are variable but generally include provisions for suspended solids removal. Four plants report the use of filtration and four the use of settling tanks. Treatment by adsorption is reported by one facility, and two report pH adjustment. Some facilities discharge without treatment, and the use of contractor hauling for disposal of some waste streams is common.

Lithium Subcategory

This subcategory encompasses the manufacture of batteries which employ lithium as the reactive anode material. At present, the batteries included in this subcategory are generally high-cost, special purpose products manufactured in limited volumes. These include batteries for heart pacemakers, lanterns, watches, and special military applications. A variety of cell cathode materials are presently used with lithium anodes including iodine, sulfur dioxide, thionyl chloride and iron disulfide. Electrolytes in these cells are generally not aqueous and may be either solid or liquid organic materials or ionic salts (used in thermally activated cells).

Because the commercial manufacture of lithium anode batteries is relatively new and rapidly changing, 1976 production figures were not available in all cases. Three of seven plants reporting lithium anode battery manufacture, reported production for 1977, 1978 and 1979 because the facilities had commenced operation after 1976. Based on 1976 figures where available and data for other years where necessary, total annual production of lithium anode cells is estimated to be over 22.2 metric tons (24.5 tons). Individual plant production ranges from less than 50 kg (100 lbs) to 14 metric tons (15.5 tons). Total employment for this subcategory is estimated to be 400.

Because of lithium's high reactivity with water, anode processing and most cell assembly operations are performed without the use of process water. In fact they are usually accomplished in areas of controlled low humidity. Process water is used, however, in producing some cell cathodes, either in washing reactive materials or for air pollution

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control and area clean-up. One plant also reports process water use in manufacturing reactive materials for activating thermal batteries as discussed in conjunction with calcium anode batteries. Three of seven plants manufacturing lithium anode batteries reported process wastewater discharges which ranged from 3.9 l/hr (1.0 gal/hr) to 150 l/hr (39 gal/hr). The maximum reported flow rate includes 60 l/hr (16 gal/hr) resulting from the manufacture of heating elements.

Wastewater streams from plants in this subcategory may be expected to vary considerably in their chemical composition due to the widely varying raw materials and processes used. Raw materials reported to be used in lithium anode battery manufacture are shown in Table III-6.

TABLE III-6
RAW MATERIALS USED IN LITHIUM ANODE BATTERY
MANUFACTURE

Acetonitrile	Lithium Perchlorate
Aluminum	Methyl Acetate
Aluminum Chloride	Methyl Formate
Barium Chromate	Nickel
Carbon	Oil
Dioxolane	Paper
Glass Fiber	Poly-2-Vinyl Pyridine
Hydrochloric Acid	Potassium Chloride
Iodine	Potassium Perchlorate
Iron	Steel
Iron Disulfide	Sulfur
Isopropyl Alcohol	Sulfur Dioxide
Lead	Teflon
Lead Iodide	Tetraphenyl Boron
Lithium	Thionyl Chloride
Lithium Bromide	Titanium Disulfide
Lithium Chloride	Vanadium Pentoxide
Lithium Fluoborate	Zirconium

Pollutants reported to be present include lead, chromium and cadmium. In addition, asbestos, iron, lithium, sodium sulfite and suspended solids may be anticipated in waste streams from specific operations. Cadmium results from electroplating cell uses and is therefore not attributable to operations included for regulation under this subcategory. Chromium and asbestos originate in the manufacture of thermal activators for high temperature military batteries as discussed for calcium anode cells. Wastewater treatment and control practices at these plants are limited to settling and pH adjustment.

Magnesium Subcategory

The magnesium subcategory encompasses the manufacture of magnesium-carbon batteries, magnesium-vanadium pentoxide thermal cells, ammonia activated magnesium anode cells, and several different types of magnesium reserve cells using metal chloride cathodes. These cell types are manufactured at eight plants with total annual production amounting to 1220 metric tons (1340 tons). Annual production at individual plants range from 0.4 metric tons (0.5 tons) to 570 metric tons (630 tons) of magnesium anode batteries. Over 85 percent of all magnesium anode batteries produced are magnesium carbon cells. Total employment for this subcategory is estimated to be 350.

A wide variety of raw materials are used in the manufacture of magnesium anode batteries due to the diversity of cell types manufactured. While the anode is magnesium in every case, principal raw materials used in cathode manufacture include manganese dioxide, barium chromate, lithium chromate, magnesium hydroxide and carbon for magnesium-carbon batteries; vanadium pentoxide for thermal batteries; copper chloride, lead chloride, silver, or silver chloride for magnesium reserve cells, and m-dinitrobenzene for ammonia activated cells. Electrolyte raw materials for these cells include magnesium perchlorate, magnesium bromide and ammonia. Separators are most often reported to be cotton or paper.

As for raw materials, product and process differences among plants in this subcategory result in significant variability in wastewater flow rates and characteristics. The production of process wastewater is reported by four of the eight plants active in this subcategory. Processes reported to yield process wastewater include alkaline and acid cleaning and chromating of magnesium anodes (which is not considered as battery process wastewater), chemical reduction and electrolytic oxidation processes in the production of silver chloride cathodes, fume scrubbers, battery testing, separator processing, and activator manufacture for thermal batteries. Process wastewater from only one of these sources was reported by two plants. All other waste streams were indicated by only one manufacturer of magnesium anode batteries. This diversity among plants in sources of wastewater is reflected in discharge flow rates which range from 0 to 5200 l/hr (1370 gal/hr) or when normalized based on the weight of cells produced, from 0 to 1,160 l/kg (139 gal/lb). The average discharge flow rate from plants in this subcategory is 670 l/hr (180 gal/hr) equivalent to 8.8 l/kg (1.05 gal/lb) of magnesium anode batteries produced.

Significant pollutants in wastewater streams resulting from magnesium anode battery manufacture include hexavalent chromium, silver, lead, fluorides, oil and grease, ammonia and suspended solids. Treatment practices presently applied to these wastes include chemical chromium

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reduction, pH adjustment, filtration, and settling. Three plants utilize pH adjustment of these wastes and two provide solids removal in settling tanks. Filtration and chromium reduction are each practiced by only one plant.

Zinc Subcategory

Zinc anode alkaline electrolyte batteries are presently manufactured using six different cathode reactants: manganese dioxide, mercuric oxide, nickel hydroxide, monovalent and divalent oxides of silver, and atmospheric oxygen. A wide range of cell size, electrical capacities and configurations are manufactured, and both primary and secondary (rechargeable) batteries are produced within this subcategory. The manufacture of zinc-anode alkaline electrolyte batteries is increasing as new battery designs and applications are developed. These products presently find use in widely varying applications including toys and calculators, flashlights, satellites and railroad signals. In the future, zinc anode batteries may provide motive power for automobiles.

In 1976, seventeen plants produced approximately 23,000 metric tons (25,000 tons) of batteries in this subcategory. Individual plant production of zinc anode alkaline electrolyte batteries ranged from 0.36 metric tons (0.40 tons) to 7,000 metric tons (7,700 tons).

Of the sixteen plants currently producing batteries, five manufacture more than one type of battery within this subcategory. Employment for this subcategory is estimated to be 4680.

Raw materials used in producing these batteries include zinc, zinc oxide, mercury, manganese dioxide, carbon, silver, silver oxide, silver peroxide, mercuric oxide, nickel and nickel compounds, cadmium oxide, potassium hydroxide, sodium hydroxide, steel and paper. Zinc is obtained either as a powder or as cast electrodes depending on the type of cell being produced. Process raw materials at specific plants vary significantly depending on both the products produced and the production processes employed. Zinc and zinc oxide are both used to produce zinc anodes. Mercury is used both to produce mercuric oxide cell cathode material and to amalgamate zinc anodes to limit cell corrosion and self discharge. Manganese dioxide is blended with carbon to form cathodes for alkaline manganese cells and is also included in cathode mixes for some mercury and silver oxide batteries. Silver is used in the form of wire screen as a support grid for cell electrodes, and in the form of powder for the production of silver oxide cathode materials. Silver oxide is used in the production of both silver oxide and silver peroxide cell cathodes, and silver peroxide is also obtained directly for use in silver oxide cell cathodes. Nickel and nickel compounds are used in producing cathodes for nickel-zinc batteries identical to those used in some nickel-cadmium batteries. Potassium and sodium hydroxide are

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used in cell electrolytes which may also include zinc oxide and mercuric oxide, and also as reagents in various process steps. Steel is used in cell cases, and paper and plastics in cell separators and insulating components.

Process water use and wastewater generation is highly variable among the products and manufacturing processes included in this subcategory. In general terms, major points of water use and discharge include zinc anode amalgamation, electrodeposition of electrode reactive materials, oxidation and reduction of electrode materials, nickel cathode impregnation and formation, cell wash, equipment cleaning, sinks and showers, and floor wash. Only some of these uses and discharge sources are encountered at each plant, and their relative significance varies.

The total volume of process wastewater produced varies from 4 l/hr (1 gal/hr) to 26,000 l/hr (7,000 gal/hr) and averages 4,300 l/hr (1,100 gal/hr). In terms of the weight of cells produced, this corresponds to a maximum flow of 400 l/kg (48 gal/lb) and an average flow per unit of product of 3.8 l/kg (0.46 gal/lb).

The pollutants found in waste streams from plants producing batteries in this subcategory are primarily metals. Zinc and mercury are encountered in most wastewater streams. Silver, mercury, and nickel are found in waste streams resulting from the manufacture of specific cell types, and hexavalent chromium is found in some waste streams as a result of the use of chromates in cell wash operations. Wastewater discharges in this subcategory are predominantly alkaline, and may contain significant concentrations of suspended solids. Oil and grease and organic pollutants are also encountered. Wastewater treatment provided is also variable, but commonly includes solids removal by settling or filtration (eleven plants). Sulfide precipitation is practiced at two sites, oil skimming at one, and ion exchange at one facility. Several plants employ amalgamation with zinc for the removal of mercury from process waste streams from this subcategory. Most treatment is provided as pretreatment for discharge to POTW since twelve plants discharge to municipal sewers.

INDUSTRY OUTLOOK

The pattern of strong growth and rapid change which has characterized the battery industry during the past decade may be expected to continue in the future. A number of technological changes which have occured in recent years and which are anticipated in the near future are creating strong demand for existing battery products and for new ones.

The advent of transistor electronics, and subsequently of integrated circuits, light emitting diodes and liquid crystal devices has

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resulted in the development of innumerable portable electronic devices such as radios, calculators, toys and games, which are powered by batteries. This has resulted in the development of new mass markets for cells in small sizes and led to the rapid commercialization of new cell types. The extremely low power drains of some digital electronic devices have created markets for low power high energy density, long life cells and resulted in the commercial development of silver oxide-zinc and lithium batteries. Solid state technology has also reduced or eliminated markets for some battery types, most notably mercury (Weston) cells which were widely used as a voltage reference in vacuum tube circuits. Continued rapid change in electronics and growth in consumer applications is anticipated with corresponding change and growth in battery markets.

In transportation technology and power generation, tightening fuel supplies and increasing costs are directing increased attention toward electrical energy storage devices. The development and increasing use of battery powered electric automobiles and trucks is creating an increasing market for large battery sizes with high energy and power densities. Increasing application of batteries for peak shaving in electrical power systems is also an anticipated development creating higher demand for batteries in larger sizes.

In summary, while, as with Lalande, Edison and Weston cells in the past, some battery types may become obsolete, the overall outlook is for rapid growth within the battery industry. Increased production of many current products, and the development of new battery types are likely. Based on general industry patterns, conversion of battery plants from one type of product to another is more likely than plant closings where demand for specific battery types is not strong.
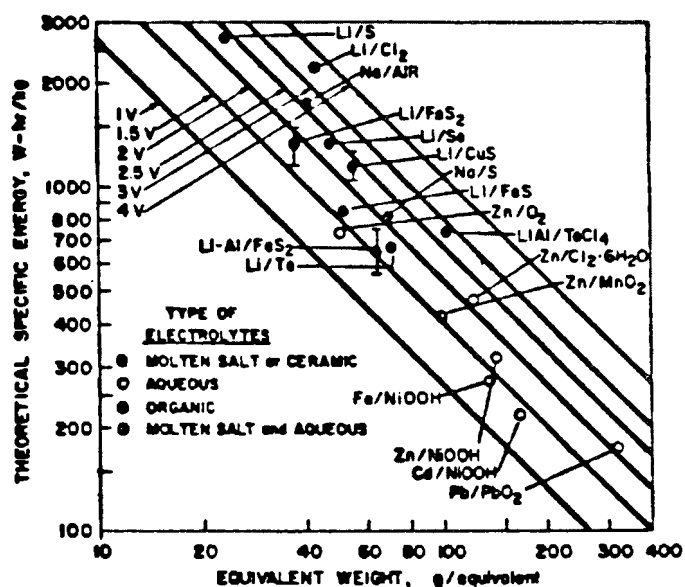
FIGURE III-1

THEORETICAL SPECIFIC ENERGY AS A .FUNCTION
OF EQUIVALENT WEIGHT AND CELL VOLTAGE
FOR VARIOUS ELECTROLYTIC COUPLES

46
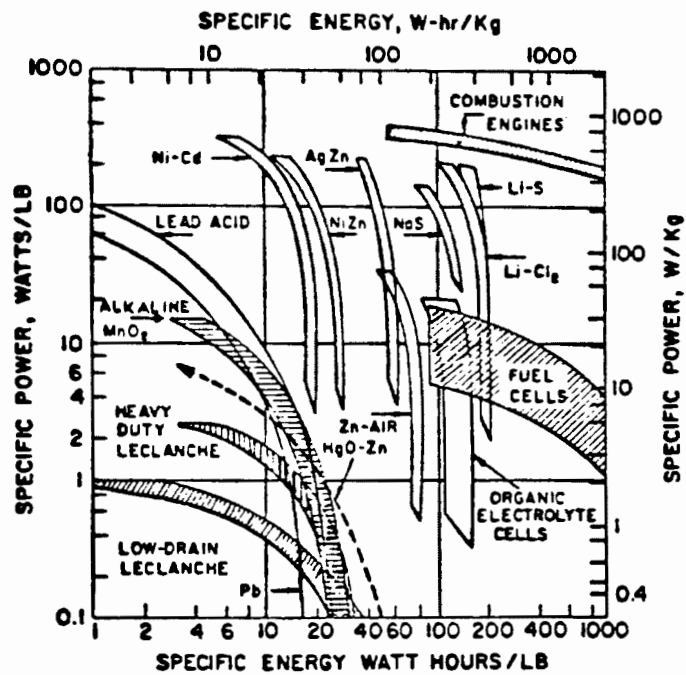
FIGURE III-2

PERFORMANCE CAPABILITY OF VARIOUS BATTERY SYSTEMS

Terminal

Vent Cap

Cell Cover

Baffle

Negative Plate

Separator

Positive Plate

Cell Jar

Terminal Comb

Plate Tabs

Electrolyte

Plate Pack

6-9 Inches
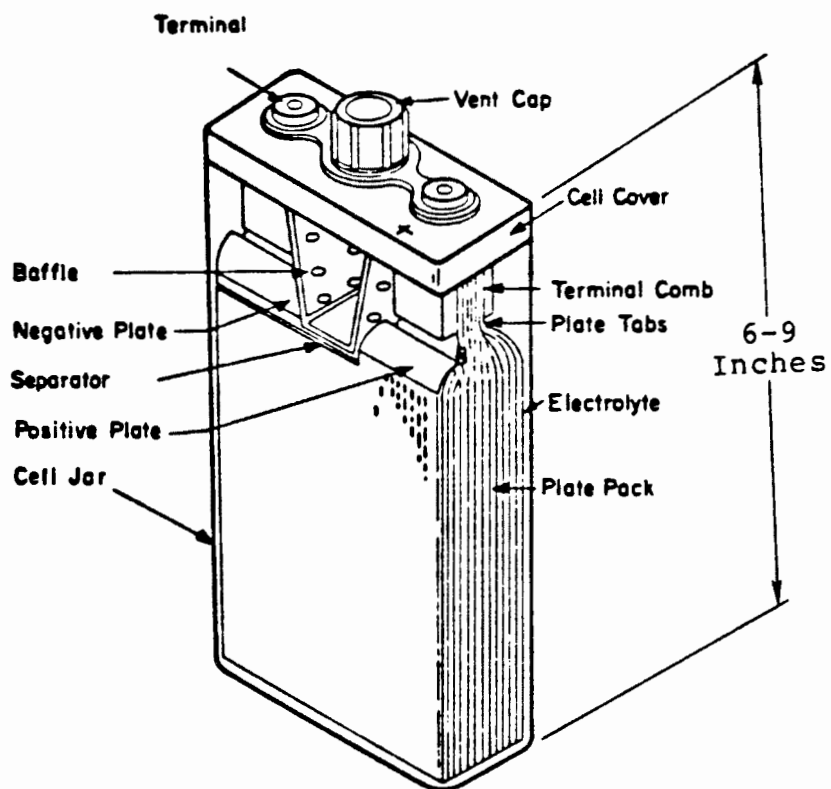
FIGURE III-3

CUTAWAY VIEW OF AN IMPREGNATED SINTERED

PLATE NICKEL-CADMIUM CELL

(Similar In Physical Structure To Some
Silver Oxide-Zinc And Nickel-Zinc Cells)
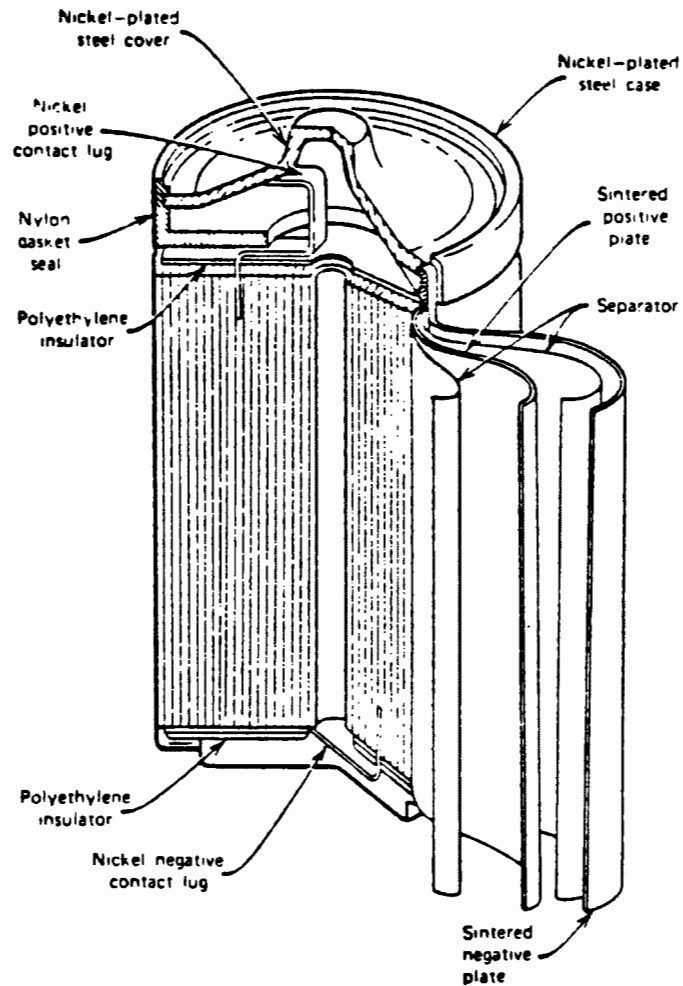
FIGURE III-4

CUTAWAY VIEW OF A CYLINDRICAL
NICKEL-CADMIUM BATTERY

(Similar In Physical Structure To
Cylindrical Lead Acid Batteries)

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Figure labels: Inter-cell Connector, Vent Plug, Post, Cover, Negative Strap, Positive Strap, Partition, Positive Plate, Separator, Container, Negative Plate, Rib, 6-12 Inches
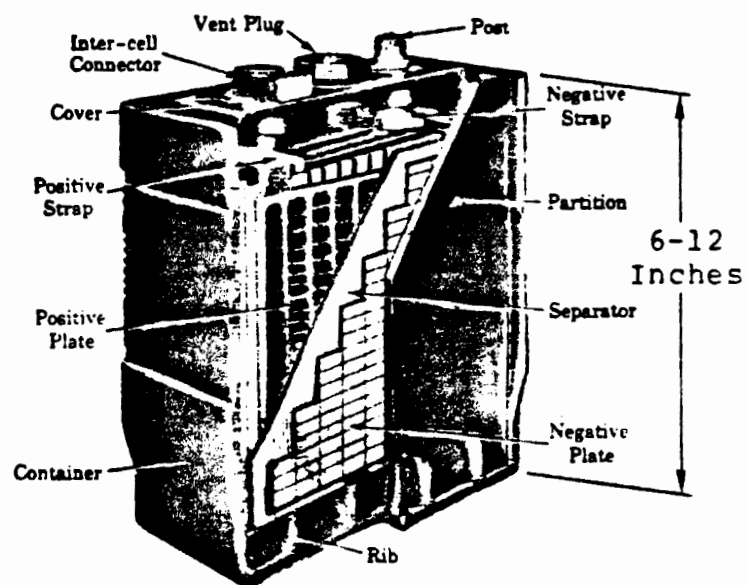
FIGURE 3-5

CUTAWAY VIEW OF LEAD ACID STORAGE BATTERY
(Without electrolyte)
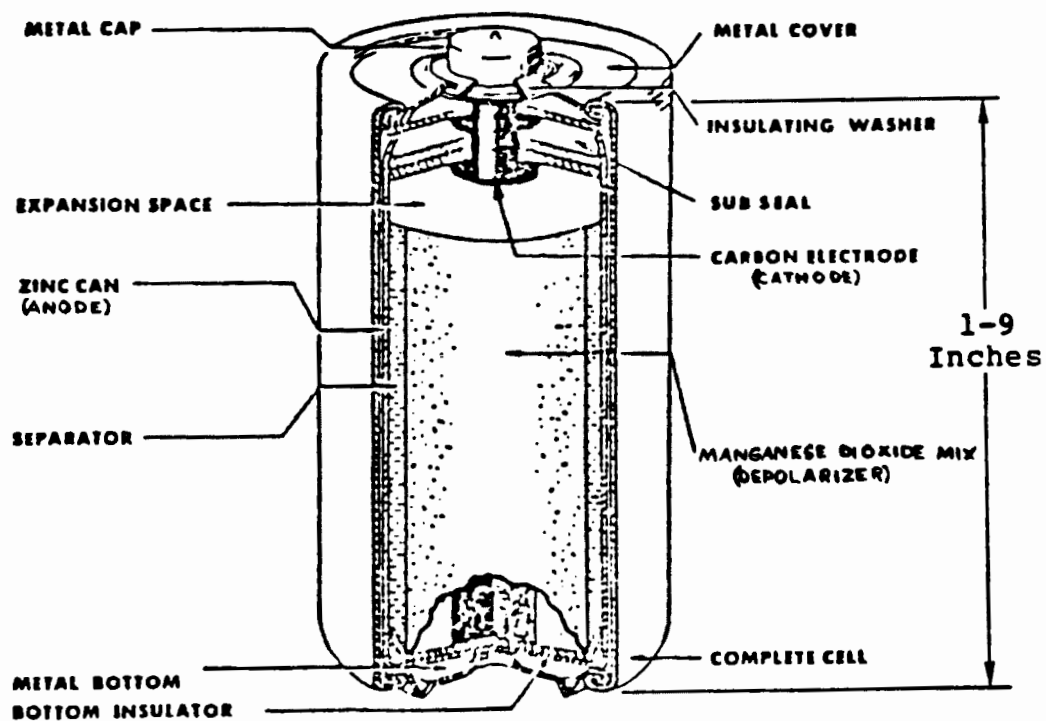
FIGURE III-6

CUTAWAY VIEW OF A LECLANCHE CELL

(Similar In Physical Structure To Carbon-Zinc-Air
And Silver Chloride-Zinc Dry Cells)

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Negative End (-)

Steel Covered With Conductive
Plastic Bearing A Patch
Of Zinc On The Underside
(Steel wraps around
steel at other end)

Manganese
Dioxide

Duplexes
(Conductive Plastic-
Upper Side Manganese
Dioxide, Lower Side Zinc)

Zinc

Connector
(Conductive sheet)

Separator Containing
Electrolyte

1.5
Volt
Cell

Adhesive Around Edge
Of Separator

Manganese Dioxide On
Conductive Plastic On Steel

Positive End (+)

Completed Battery
Assembled On Card
With Contact Holes

Thickness, 1/4 Inch

FIGURE III-7

EXPLODED VIEW OF A FLAT LECLANCHE
BATTERY USED IN FILM PACK

POLYESTER
JACKET

CATHODE CURRENT
COLLECTOR

ANODE CURRENT
COLLECTOR

DEPOLARIZER

LITHIUM ANODE

FLUOROCARBON
PLASTIC JACKET

PLASTIC LAYERS SEPARATE
DEPOLARIZER FROM CASE

LITHIUM ENVELOPE AND
FLUOROCARBON PLASTIC JACKET
SEPARATE DEPOLARIZER FROM CASE
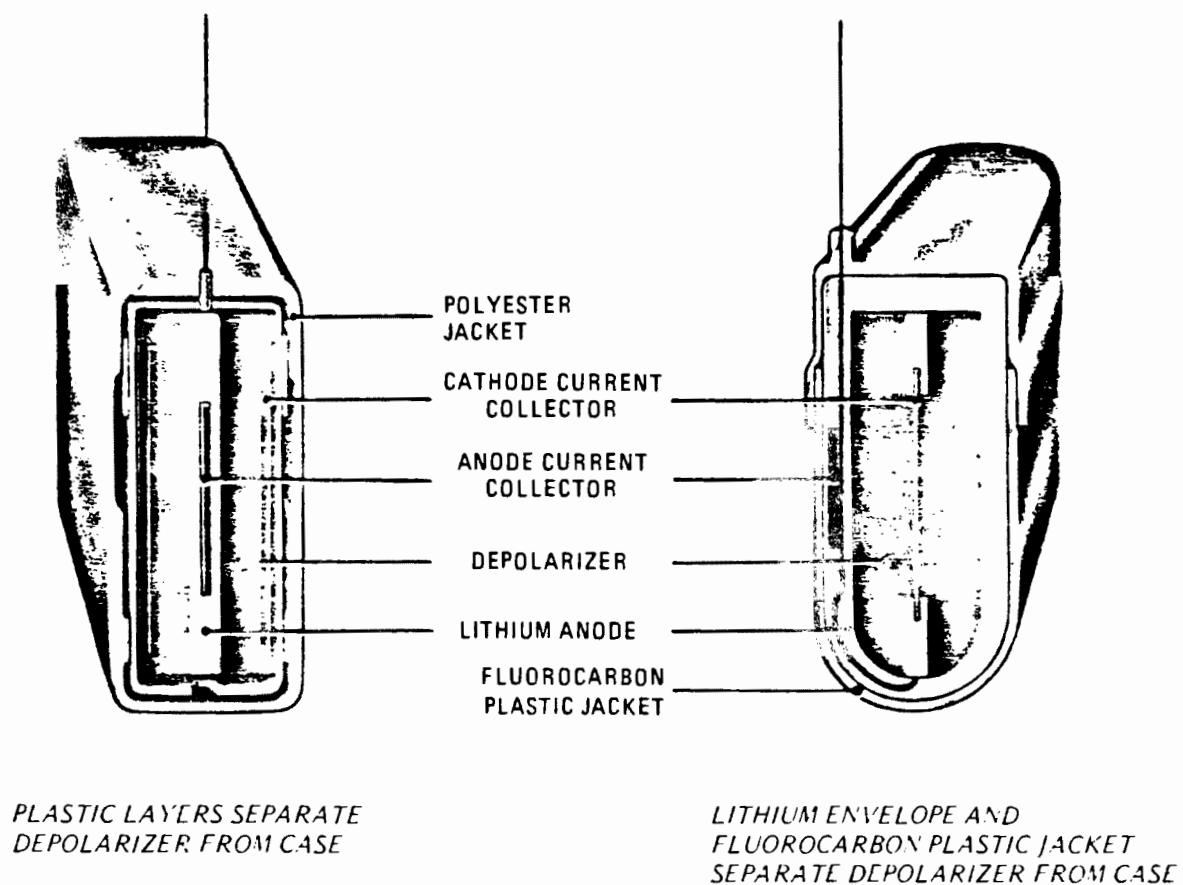
FIGURE III-8

CUTAWAY VIEW OF TWO SOLID ELECTROLYTE
LITHIUM CELL CONFIGURATIONS

53
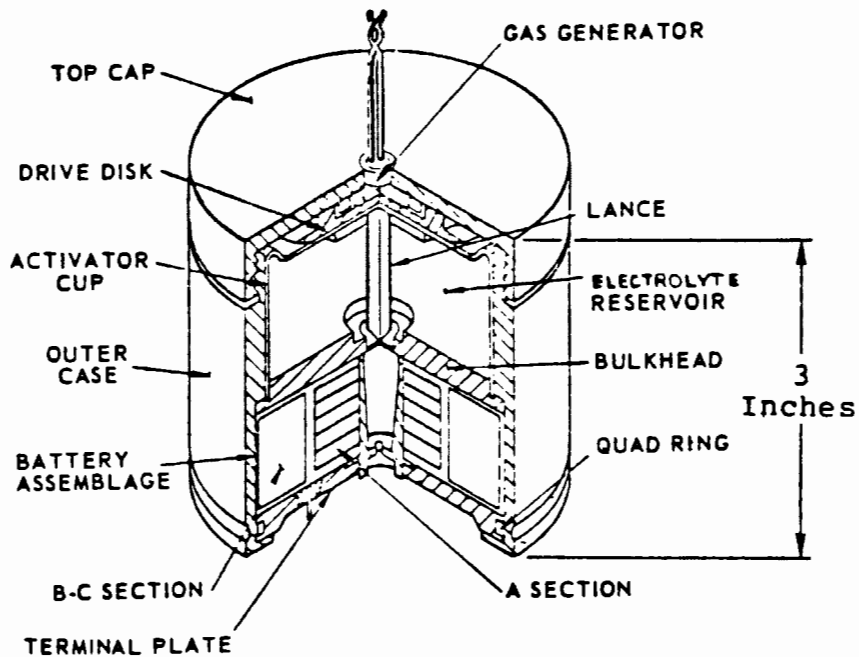
Example Shown For Liquid-Ammonia-Activated Magnesium Reserve Battery:

Cathode	- carbon depolarized meta-dinitrobenzene
Anode	- magnesium
Electrolyte	- dry ammonium thiocyanate activated by liquid ammonia

FIGURE III-9

CUTAWAY VIEW OF A RESERVE TYPE BATTERY

("A" SECTION AND "B-C" SECTION CONTAIN ANODE AND CATHODE)

Filler Tube Cap

Cast Caustic Sticks

Cylindrical Zinc Anode

Carbon Cathode

Filler Tube For Water

Mixture Of Pelleted Lime And Granular Caustic Soda
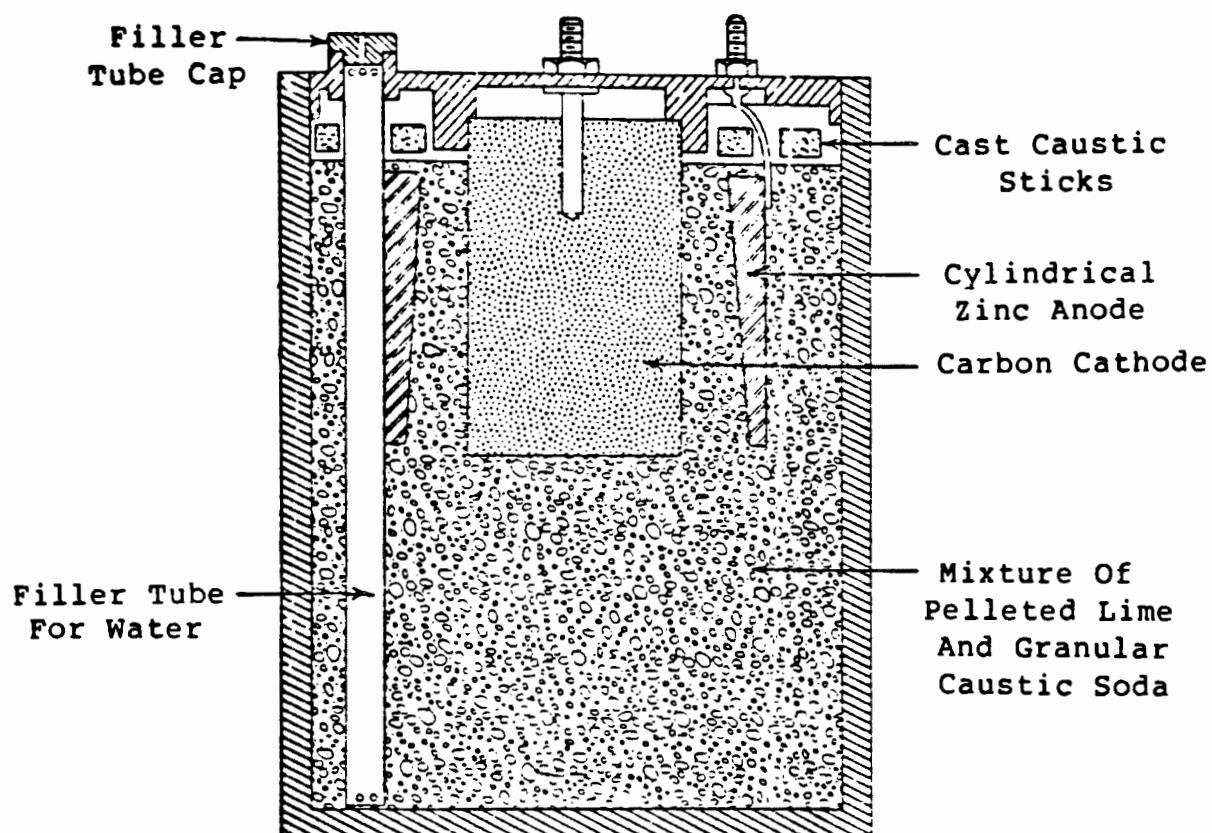
FIGURE III-10

CUTAWAY VIEW OF A CARBON-ZINC-AIR CELL

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COVER (+)

CAN

CATHODE

ANODE AND ELECTROLYTE

SEPARATOR (INSIDE)

1/4-3
Inches

METAL JACKET

INSULATING TUBE

CURRENT COLLECTOR

SEAL

INSULATOR

INNER METAL BOTTOM

PRESSURE SPRING

OUTER METAL BOTTOM (-)

RIVET
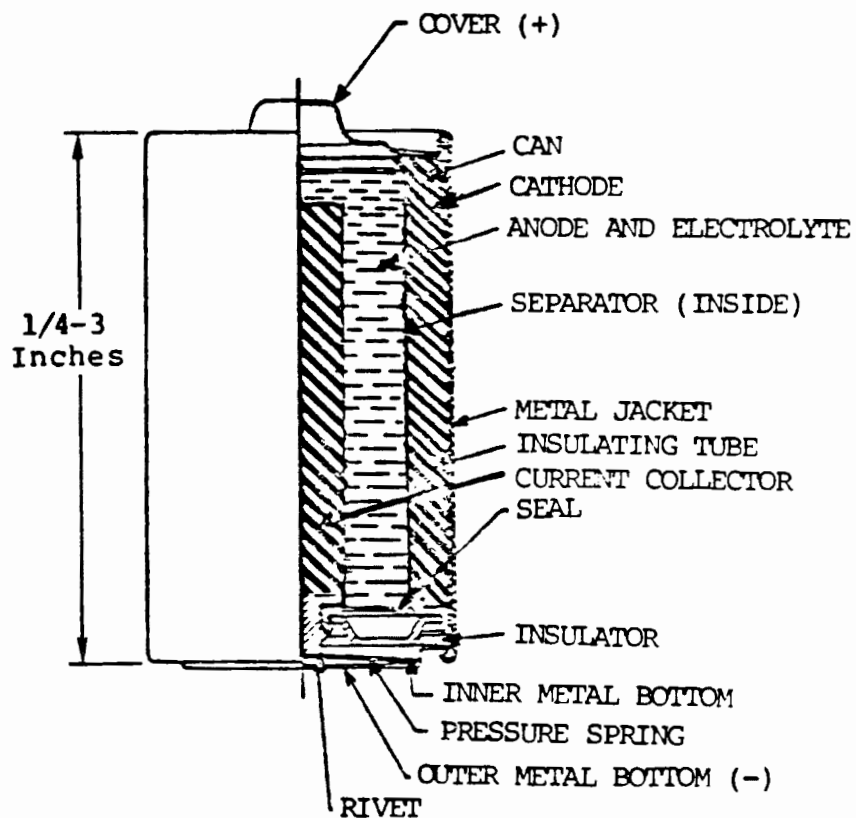
FIGURE III-11

CUTAWAY VIEW OF AN ALKALINE-MANGANESE BATTERY

(Similar In Physical Structure To
Cylindrical Mercury-Zinc Batteries)

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Cell Can

Separator

Anode

Cathode

Gasket

Anode Cup

1/8-1/2 Inches
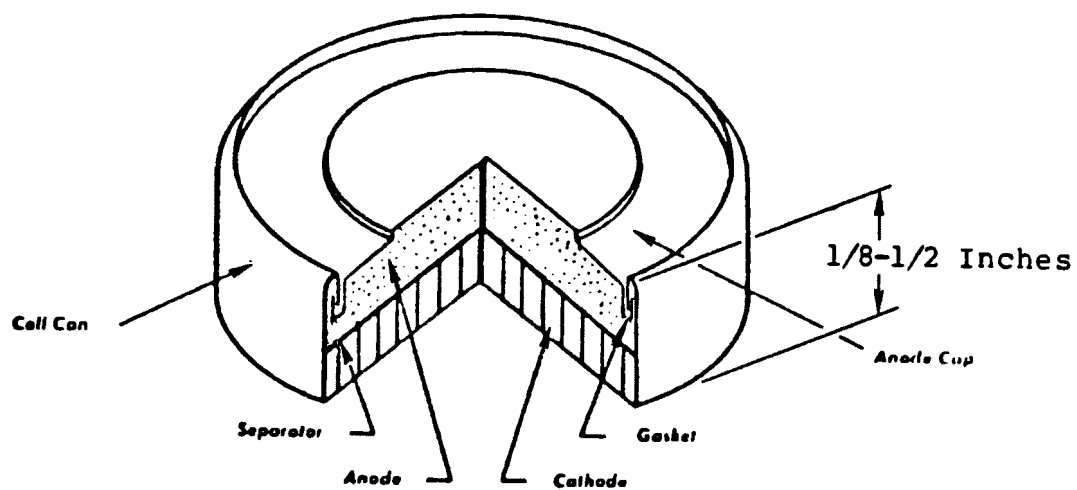
FIGURE III-12

CUTAWAY VIEW OF A MERCURY (RUBEN) CELL

(Similar In Physical Structure
To Alkaline-Manganese And
Silver Oxide-Zinc Button Cells)
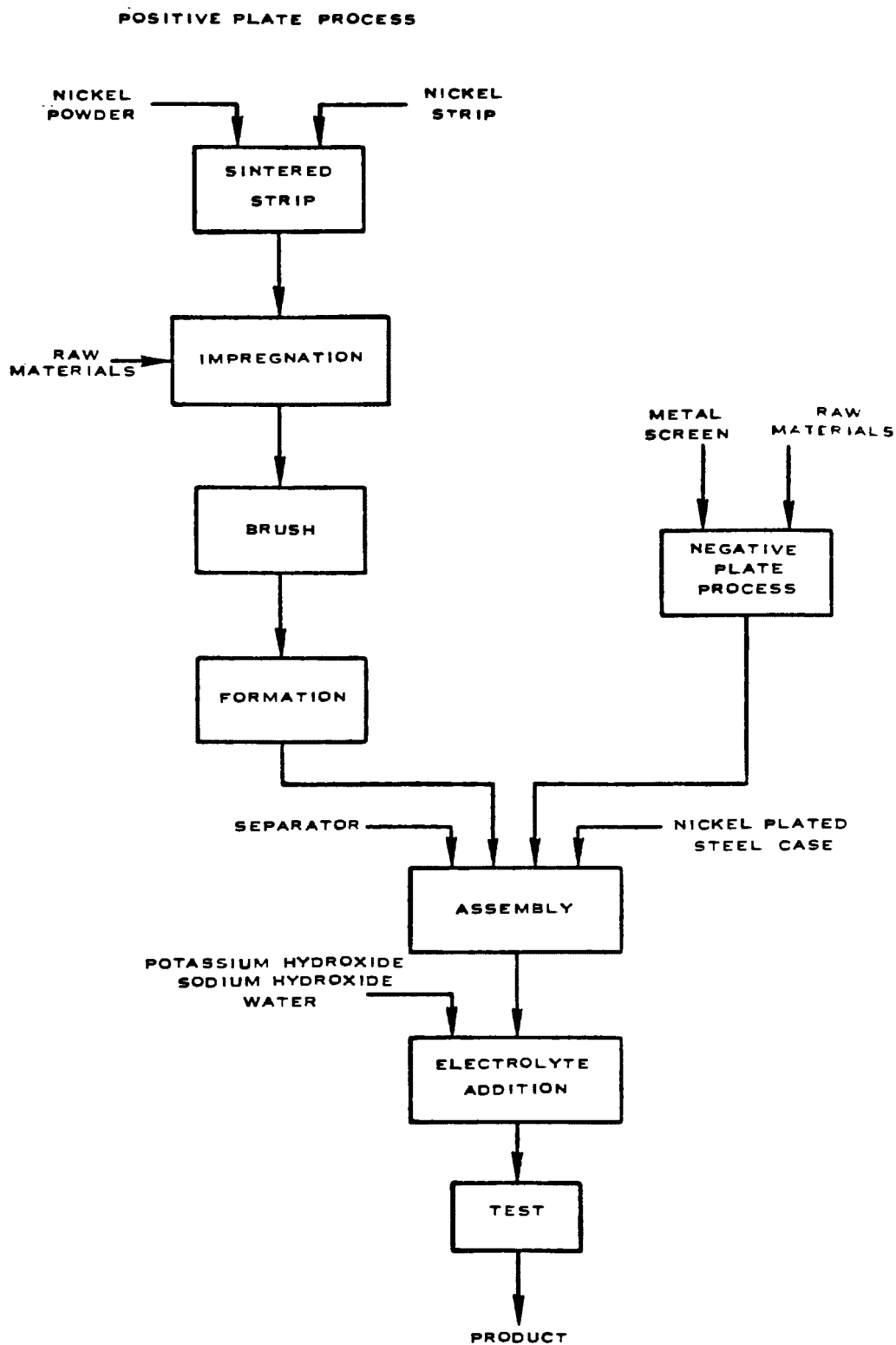
FIGURE III-13

MAJOR PRODUCTION OPERATIONS IN
NICKEL-CADMIUM BATTERY MANUFACTURE
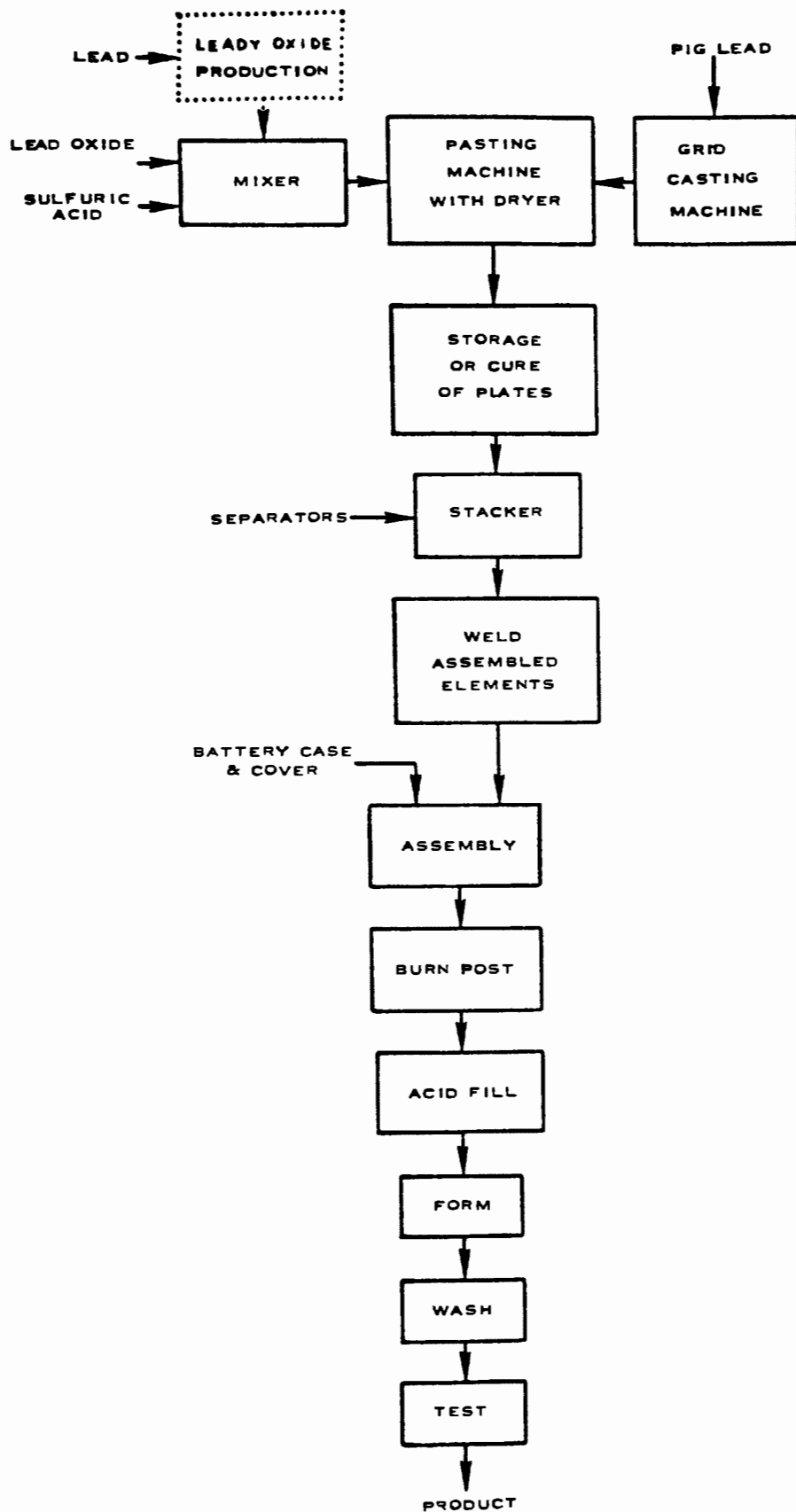
FIGURE III-14

SIMPLIFIED DIAGRAM OF MAJOR PRODUCTION OPERATIONS IN
LEAD ACID BATTERY MANUFACTURE

59
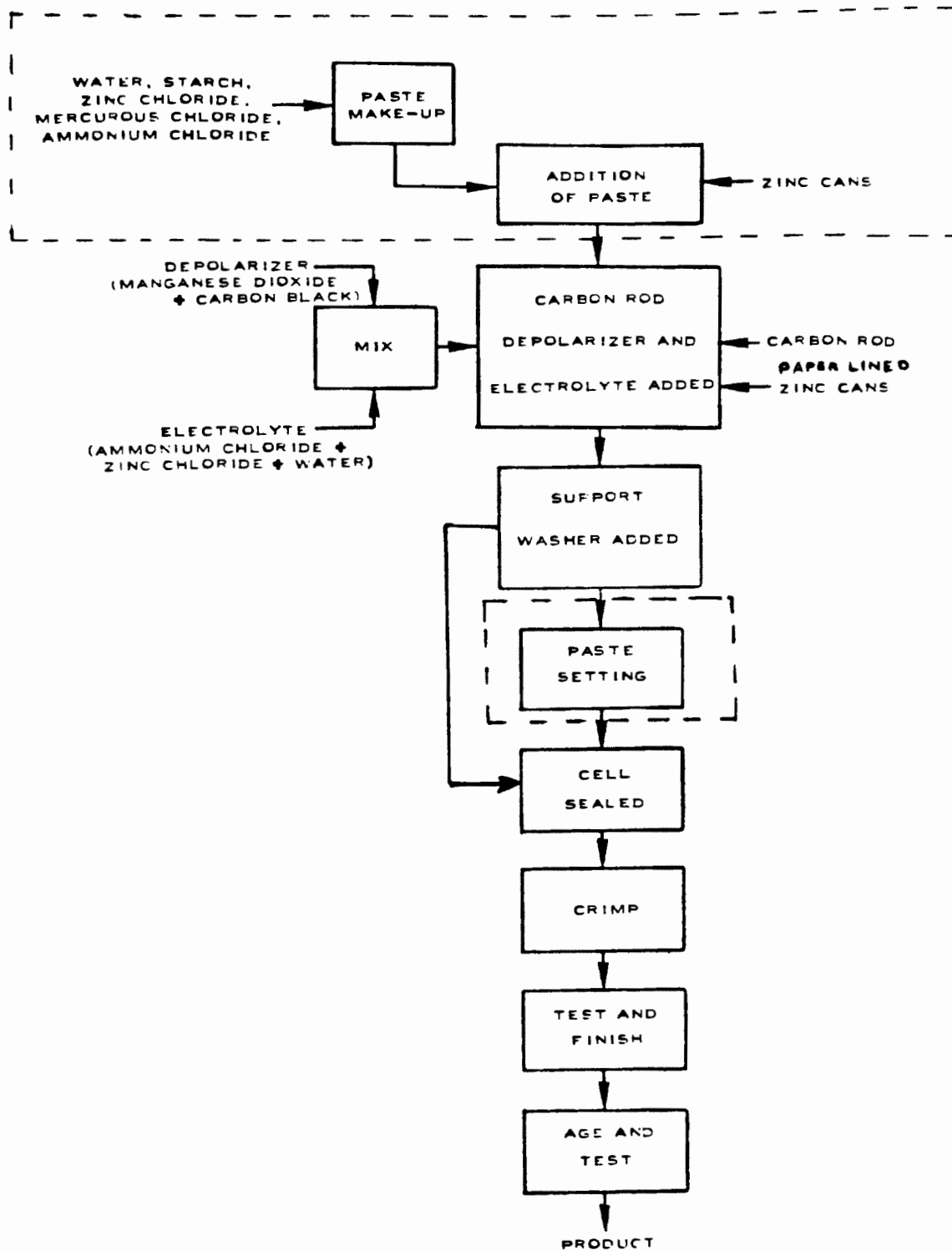
----- ALTERNATE PRODUCTION STEPS

FIGURE 3-15

MAJOR PRODUCTION OPERATIONS IN LECLANCHE
DRY BATTERY MANUFACTURE

60
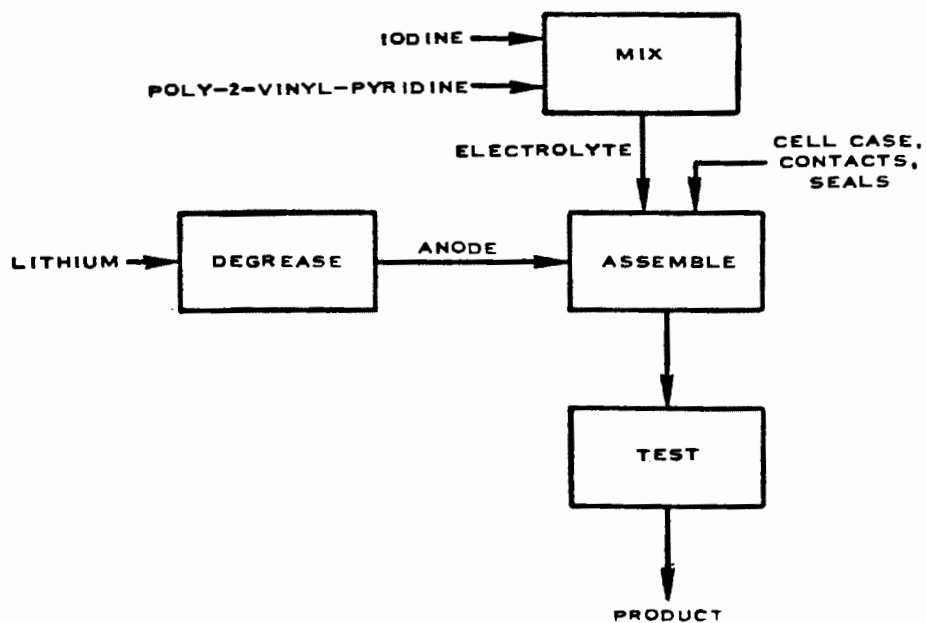
FIGURE III-16

MAJOR PRODUCTION OPERATIONS IN

LITHIUM—IODINE BATTERY MANUFACTURE

61
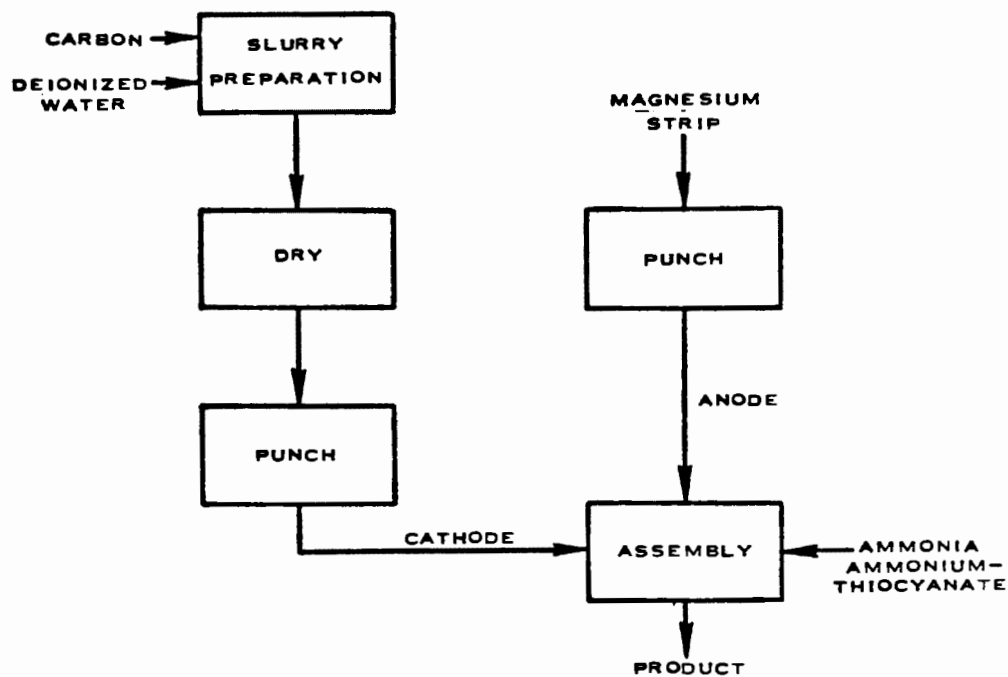
FIGURE III-17

MAJOR PRODUCTION OPERATIONS IN AMMONIA –

ACTIVATED MAGNESIUM RESERVE CELL MANUFACTURE
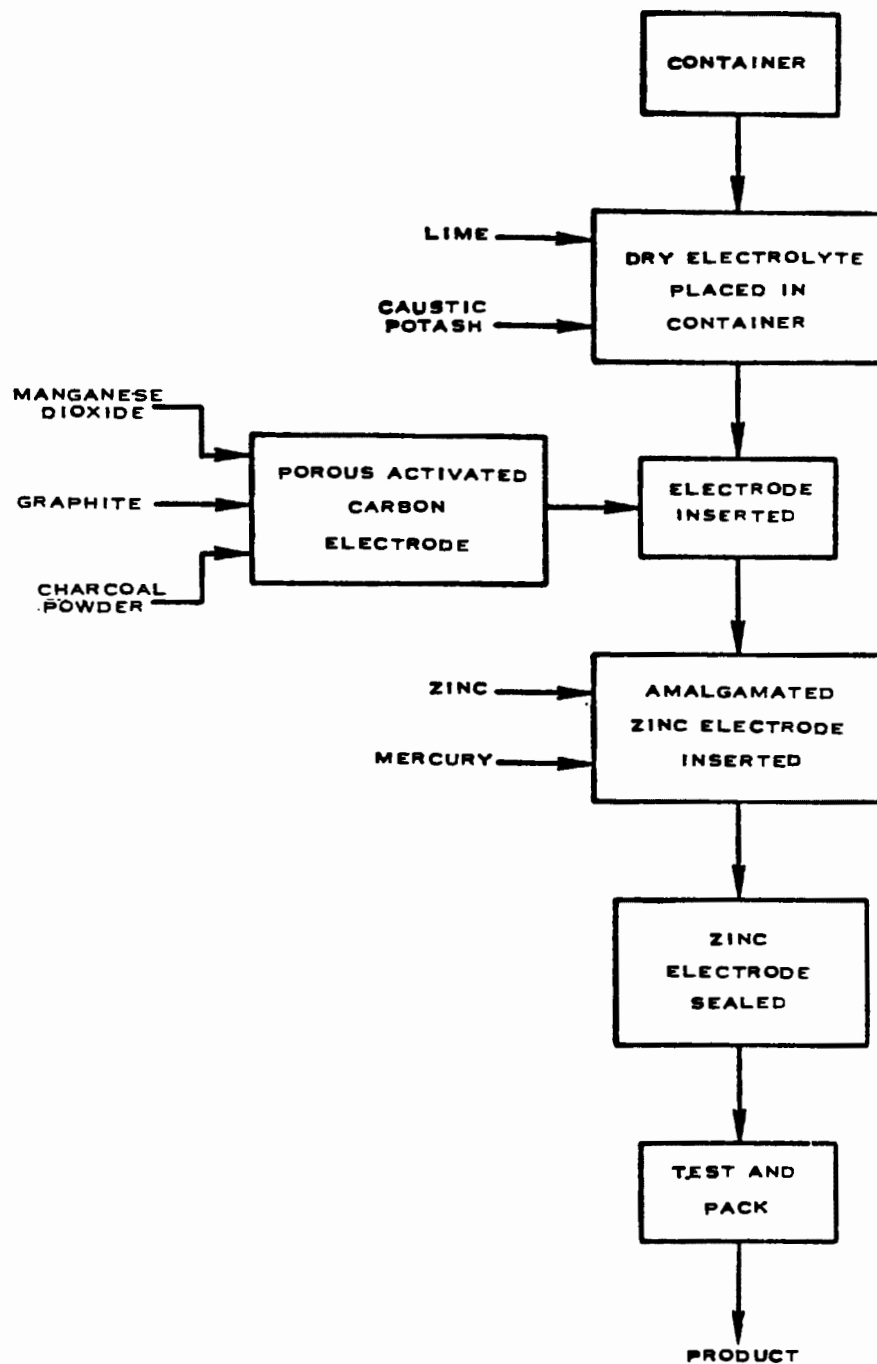
FIGURE III-18

MAJOR PRODUCTION OPERATIONS IN WATER ACTIVATED
CARBON-ZINC-AIR CELL MANUFACTURE

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BINDER
CARBON &
MANGANESE
DIOXIDE

ZINC &
MERCURY

POTASSIUM HYDROXIDE,
WATER & BINDER

```
                              FORMED INTO                                      ANODE
                                CATHODE

CONTAINER        CATHODE        SEPARATOR      ELECTROLYTE      ANODE      CURRENT           CRIMP
PRODUCED         INSERTED       INSERTED                       INSERTED   COLLECTOR
                                                                         RIVET AND
                                                                         SEAL INSERTED
```

```
PRODUCT    TEST AND    COVERS      PRESSURE     JACKET AND    PRE-TEST    CELL WASH
           PACK        ATTACHED    SPRING·      PAPER
                                   INSERTED     INSULATOR
                                                ATTACHED
```
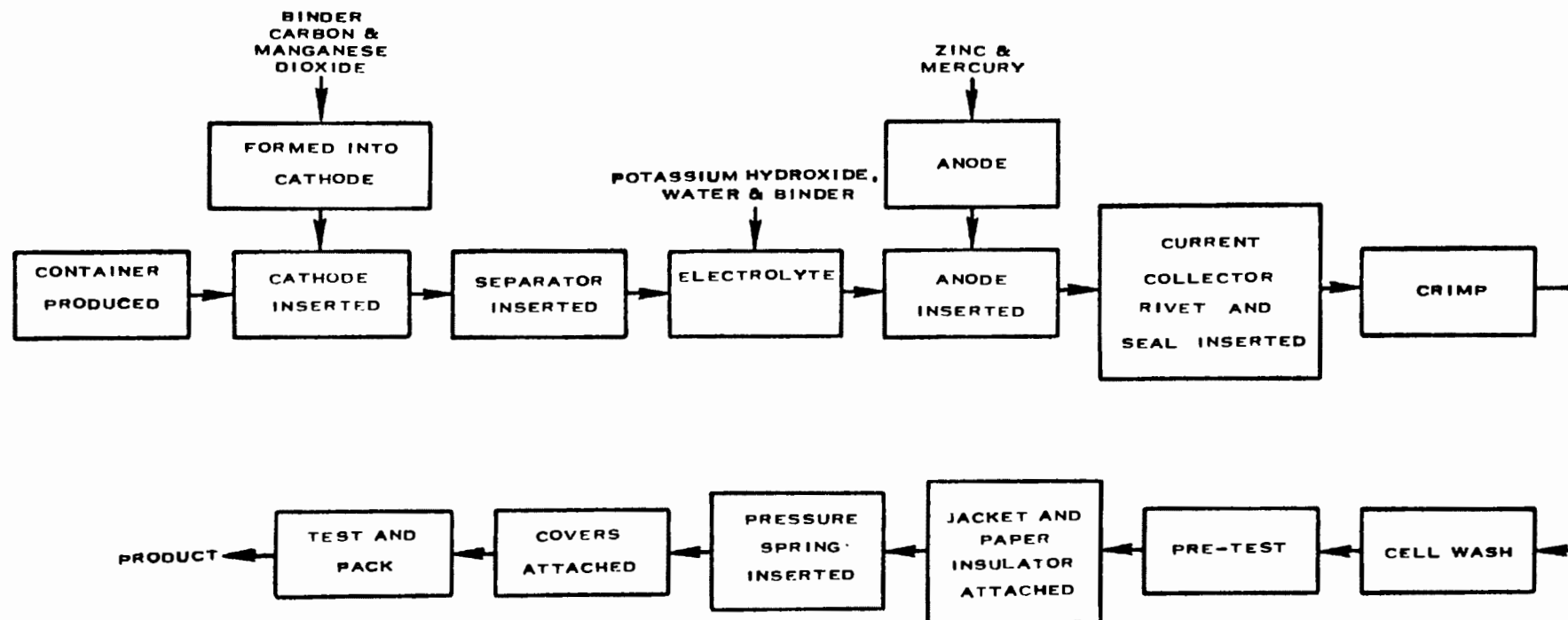
FIGURE III-19

MAJOR PRODUCTION OPERATIONS IN ALKALINE—
MANGANESE DIOXIDE BATTERY MANUFACTURE
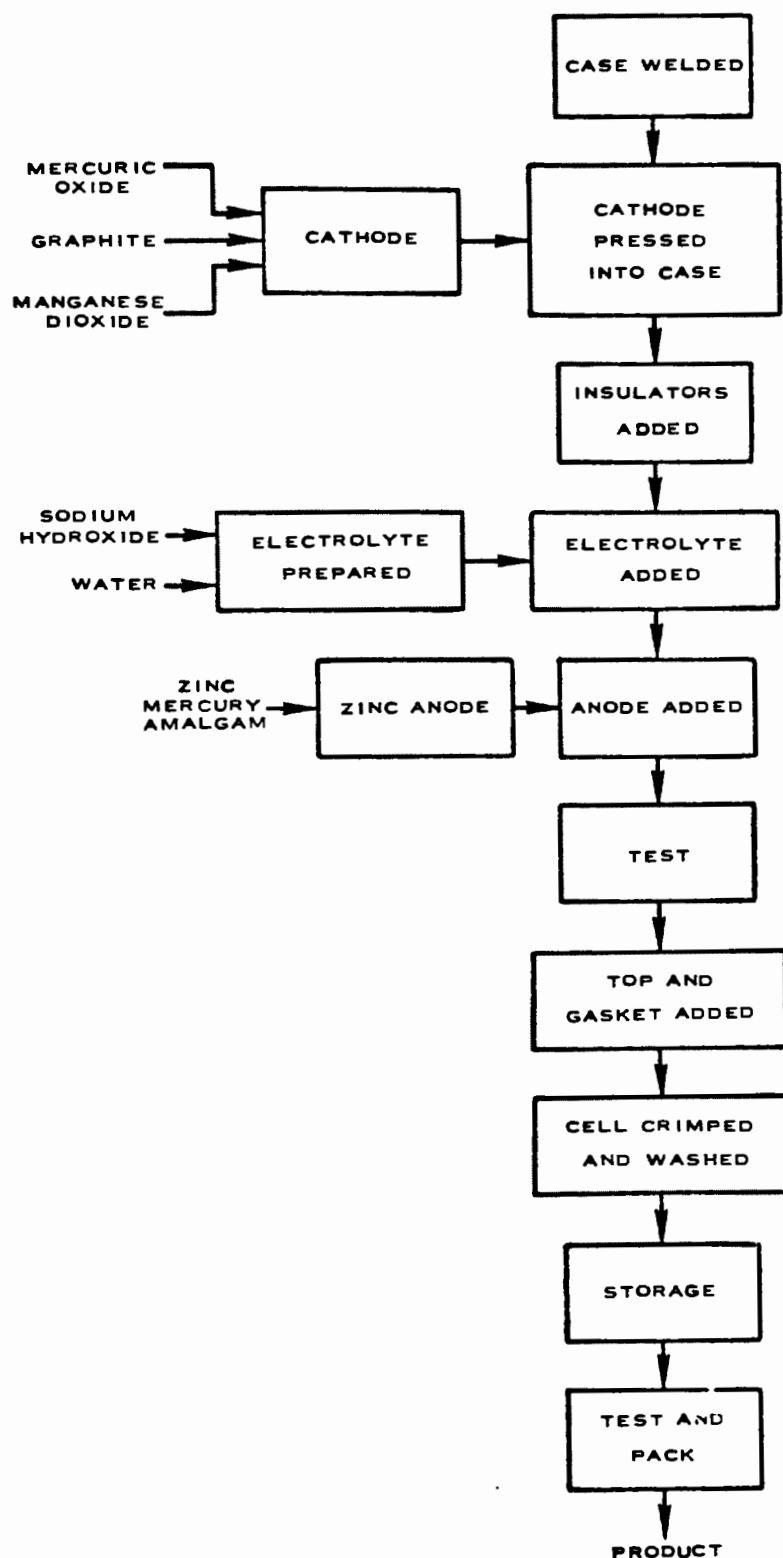
FIGURE III-20

SIMPLIFIED DIAGRAM OF MAJOR OPERATIONS

IN MERCURY (RUBEN) BATTERY MANUFACTURE

65
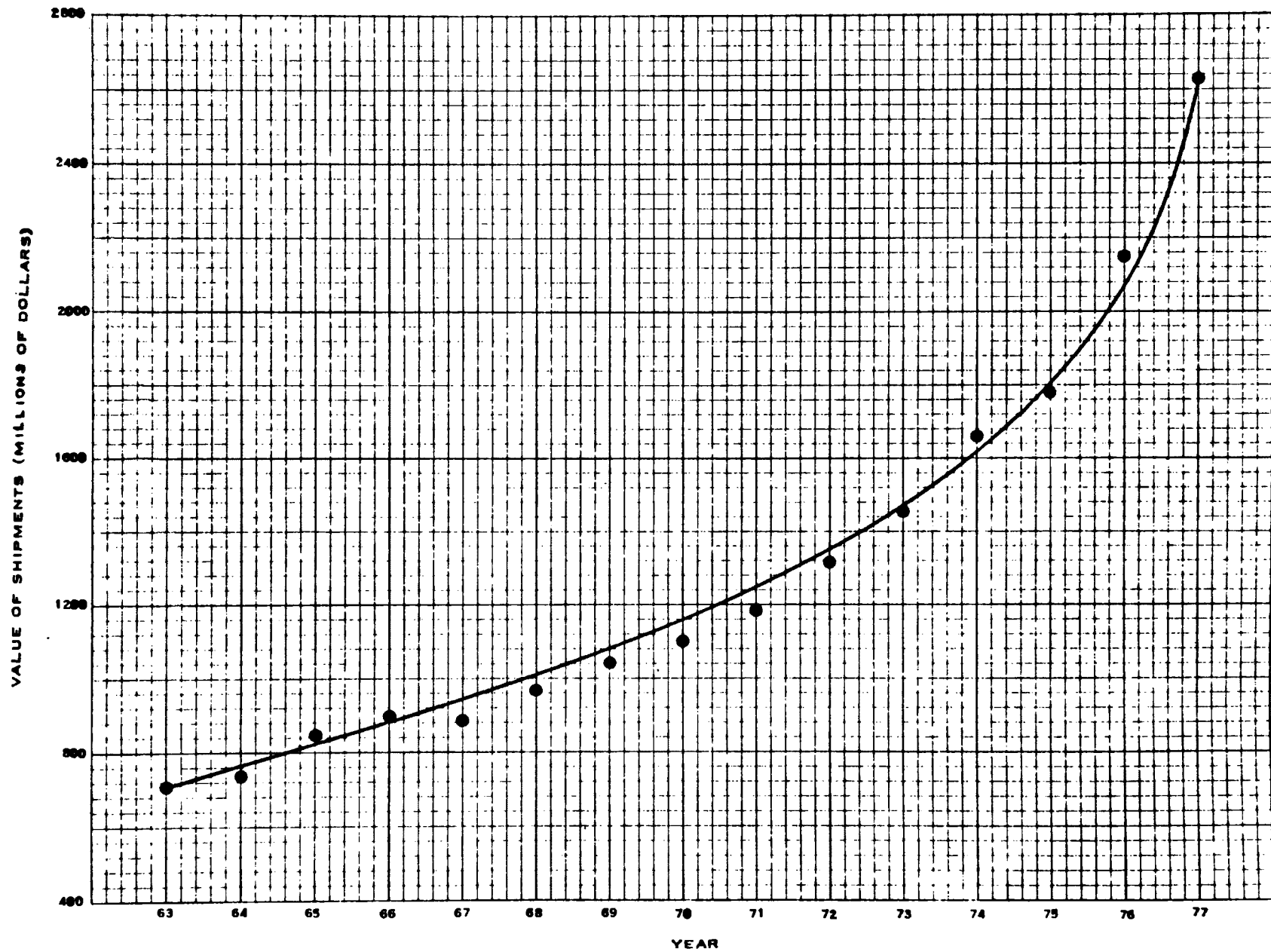
FIGURE III-21

* FROM U.S. DEPT. OF COMMERCE DATA
1977 CENSUS OF MANUFACTURERS

VALUE OF BATTERY PRODUCT SHIPMENTS 1963–1977 *

FIGURE III-22
BATTERY MANUFACTURING CATEGORY SUMMARY

Subcategory	Batteries Manufactured	Number of Plants	Estimated Total Annual Production metric tons (tons)		Estimated Total Number of Employees	Dischargers					Estimated Total Process Process Wastewater Flow l/yr (gal/yr)
						Direct	POTW	Both	Zero	Unknown	
Cadmium	Nickel-Cadmium Silver Oxide-Zinc Mercury Cadmium	10	5,250	(5,790)	2,500	2	4	1	3		6.9×10^8 (1.8×10^8)
Calcium	Thermal	3	<23	(<25)	240		2		1		1.3×10^5 (3.4×10^4)
Lead	Lead Acid Lead Acid Reserve	184	1,300,000	(1,430,000)	18,745	15	99	0	50	20	7.2×10^9 (1.9×10^9)
Leclanche	Carbon Zinc Carbon Zinc, Air Depolarized Silver Chloride-Zinc	19	108,000	(119,000)	4,200	0	7	0	12		1.5×10^7 (3.9×10^6)
Lithium	Lithium Thermal	7	<23	(<25)	400	1	4	0	2		4.9×10^5 (1.3×10^5)
Magnesium	Magnesium Carbon Magnesium Reserve Thermal	8	1,220	(1,340)	350	1	3	0	4		1.2×10^7 (3.2×10^6)
Zinc	Alkaline Manganese Silver Oxide-Zinc Mercury Zinc Carbon Zinc-Air Depolarized Nickel Zinc	16	23,000	(25,000)	4,680	2	12	0	2		6.1×10^7 (1.6×10^6)

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PRODUCTION (METRIC TONS X 10^3)
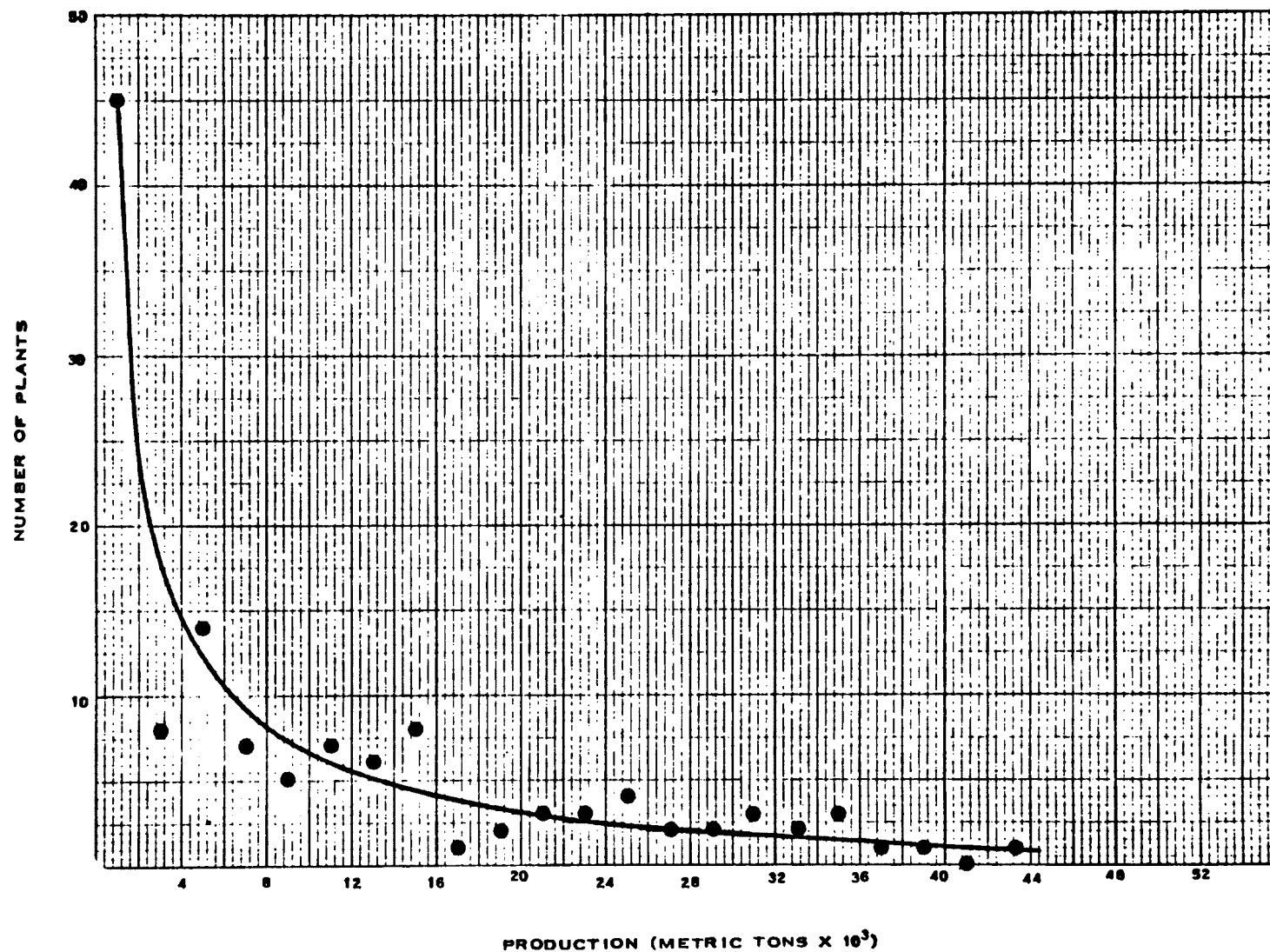
FIGURE III-23

DISTRIBUTION OF LEAD SUBCATEGORY

PRODUCTION RATES

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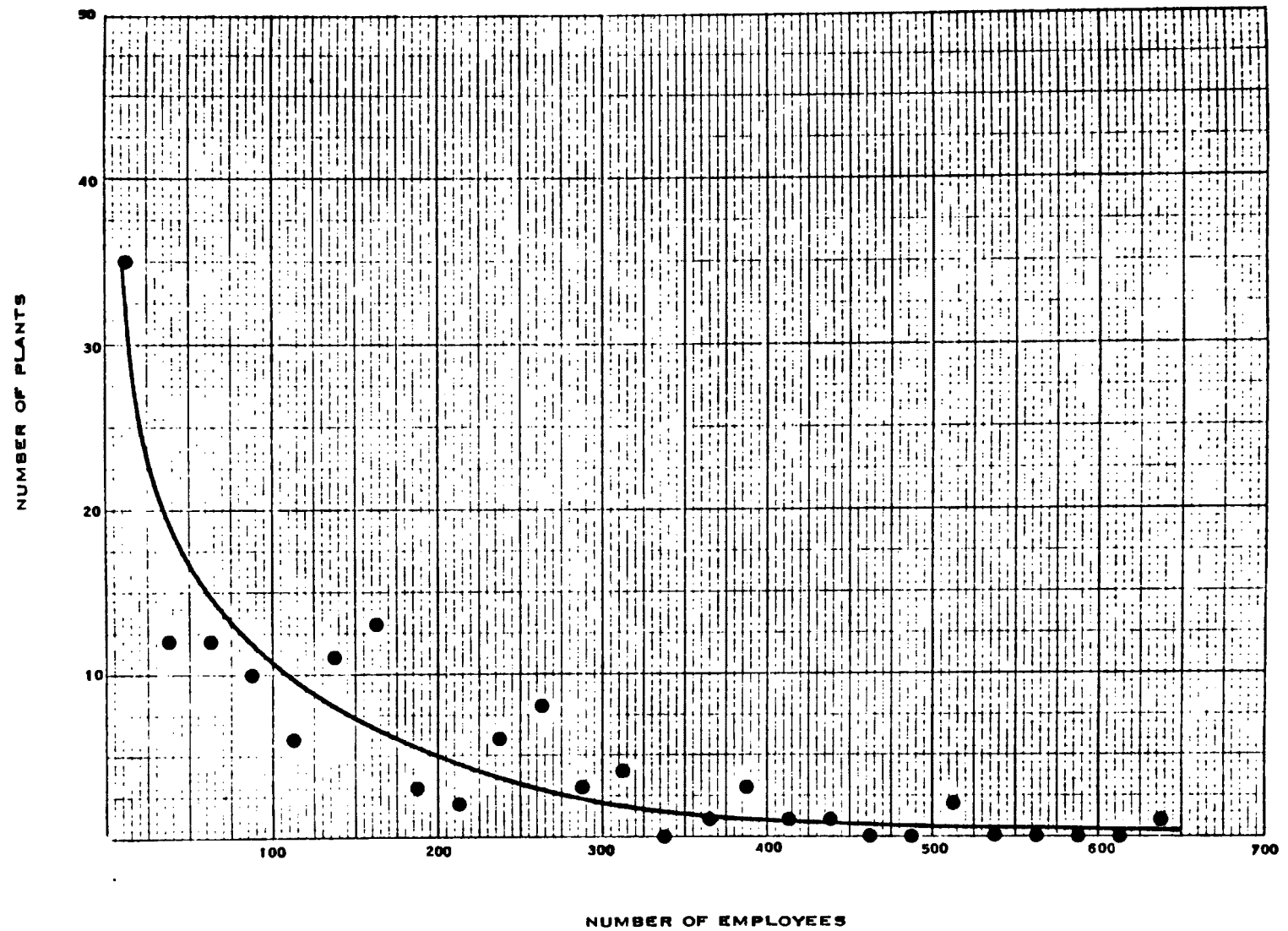
FIGURE III-24

DISTRIBUTION OF EMPLOYMENT AT LEAD
SUBCATEGORY MANUFACTURING FACILITIES

SECTION IV
INDUSTRY SUBCATEGORIZATION

Subcategorization should take into account pertinent industry characteristics, manufacturing process variations, water use, wastewater characteristics, and other factors which do or could compel a specific grouping of segments of industry for the purpose of regulating wastewater pollutants. Division of the industry segment into subcategories provides a mechanism for addressing process and product variations which result in distinct wastewater characteristics. Effluent limitations and standards establish mass limitations on the discharge of pollutants which are applied, through the permit issuance process, to specific dischargers. To allow the national standard to be applied to a wide range of sizes of production units, the mass of pollutant discharge must be referenced to a unit of production. This factor is referred to as a production normalizing parameter and is developed in conjunction with subcategorization.

In addition to processes which are specific to battery manufacturing, many battery plants report other process operations. These operations, generally involve the manufacture of components and raw materials produced on-site at some facilities or purchased at others. These operations are not considered in this document.

SUBCATEGORIZATION

Factors Considered

After examining the nature of the various segments of the battery manufacturing category and the operations performed therein, the following subcategorization factors were selected for evaluation. Each of these characteristics is discussed in the ensuing paragraphs after which the process leading to selection of the anode subcategorization is described.

1. Waste Characteristics
2. Battery Type
3. Manufacturing Processes
4. Water Use
5. Water Pollution Control Technology
6. Treatment Costs
7. Effluent Discharge Destination
8. Solid Waste Generation and Disposal
9. Size of Plant
10. Age of Plant
11. Number of Employees
12. Total Energy Requirements (Manufacturing Process and Waste Treatment and Control)

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13.   Non-Water Quality Characteristics
14.   Unique Plant Characteristics

Waste Characteristics - While subcategorization is inherently based on waste characteristics, these are primarily determined by characteristics of the manufacturing process, product, raw materials, and plant which may provide useful bases for subcategorization.

Battery Type - Battery type as designated by reactive couples or recognized battery types (as in the case of magnesium reserve or thermal cells), was initially considered a logical basis for subcategorization. This basis has two significant shortcomings. First, batteries of a given type are often manufactured using several different processes with very different wastewater generation characteristics. Second, it was found that batteries of several types were often manufactured in a single facility with some process operations (and resultant wastewater streams) common to the different battery types. Since modification of battery type subcategories to reflect all process variations and product combinations results in an intractable number of subcategories, battery type was not found to be an acceptable primary basis for subcategorization. Battery type is, however, reflected to a significant degree in manufacturing process considerations and in anode metal.

Manufacturing Processes - The processes performed in the manufacture of batteries are the wastewater sources and thus are a logical basis for the establishment of subcategories. In this category, however, similar processes may be applied to differing raw materials in the production of different battery types yielding different wastewater characteristics. For example, nickel, cadmium and zinc electrodes may all be produced by electrodeposition techniques. Further, the number of different manufacturing process sequences used in producing batteries is extremely large although a smaller number of distinct process operations are used in varying combinations. As a result of these considerations, neither overall process sequence nor specific process operations were found to be suitable as primary bases for subcategorization. However, process variations which result in significant differences in waste water generation are reflected in the manufacturing process elements for which specific discharge allowances were developed within each subcategory.

Water Use - Water usage alone is not a comprehensive enough factor upon which to subcategorize. While water use is a key element in the limitations established, it does not inherently relate to the source or the type and quantity of the waste. Water usage must be related to the manufacturing process utilizing the water since it effects the water usage and cannot be used alone as an effective categorization base.

<u>Water Pollution Control Technology, Treatment Costs, and Effluent Discharge Destination</u> - The necessity for a subcategorization factor to relate to the raw wastewater characteristics of a plant automatically eliminates certain factors from consideration as potential bases for subdividing the category. Water pollution control technology, treatment costs, and effluent discharge destination have no effect on the raw wastewater generated in a plant. The water pollution control technology employed at a plant and its costs are the result of a requirement to achieve a particular effluent level for a given raw wastewater load. It does not affect the raw wastewater characteristics. Likewise, the effluent discharge destination does not affect the raw wastewater characteristics or treatability.

<u>Solid Waste Generation and Disposal</u> - Physical and chemical solid waste characteristics generated by the manufacture of batteries can be accounted for by subcategorization according to battery type since this determines some of the resultant solid wastes from a plant. Solid waste characteristics as well as wastewater characteristics are a function of the specific battery type and manufacturing process. Furthermore, solid waste disposal techniques may be identical for a wide variety of solid wastes and do not provide a sufficient base for subcategorization.

<u>Size of Plant</u> - The size of a plant is not an appropriate subcategorization factor since the wastewater characteristics of a plant per unit of production are essentially the same for plants of all sizes that have similar processing sequences. However, the size of a facility determines the production capacity of a plant. Size is thus indirectly used to determine the effluent limitations since these are based on production rates. But, size alone is not an adequate subcategorization parameter since the wastewater characteristics of plants are also dependent on the type of processes performed as determined by the battery type manufactured.

<u>Age of Plant</u> - While the relative age of a plant may be important in considering the economic impact of a regulation, it is not an appropriate basis for grouping battery manufacturing into subcategories because it does not take into consideration the significant parameters which affect the raw wastewater characteristics. In addition, a categorization based on age would have to distinguish between old plants with old equipment, old plants with new equipment, new plants with old equipment, and every possible combination thereof. Since plants in this industry modernize and replace equipment relatively frequently, changes of subcategory would often result from this approach to make subcategorization infeasible.

<u>Number of Employees</u> - The number of employees in a plant does not directly provide a basis for subcategorization since the number of employees does not reflect either production processes used or the

production or water usage rate at any plant. Plants producing most battery types varied over a wide range in terms of number of production employees. The volume and characteristics of process wastewater was not found to have any meaningful relationship with plant employment figures.

Total Energy Requirements - Total energy requirements were excluded as a subcategorization parameter primarily because energy requirements are found to vary widely within this category and are not meaningfully related to wastewater generation and pollutant discharge. Additionally, it is often difficult to obtian reliable energy estimates specifically for production and waste treatment. When available, estimates are likely to include other energy requirements such as lighting, process, air conditioning, and heating or cooling energy.

Non-Water Quality Aspects - Non-water quality aspects may have an effect on the wastewater generated in a plant. For example, wet scrubbers may be used to satisfy air pollution control regulations. This could result in an additional contribution to the plant's wastewater flow. However, it is not the prime cause of wastewater generation in the battery manufacturing category, and therefore, not acceptable as an overall categorization factor.

Unique Plant Characteristics - Unique plant characteristics such as geographical location, space availability, and water availability do not provide a proper basis for subcategorization since they do not affect the raw waste characteristics of the plant. Dcp data indicate that plants in the same geographical area may have different wastewater characteristics. However, process water availability may be a function of the geographic location of a plant, and the price of water may necessitate individual modifications to procedures employed in plants. It has been generally observed that plants located in areas of limited water supply are more likely to practice in-process wastewater control procedures to reduce the ultimate volume of discharge. These procedures however, can also be implemented in facilities which have access to plentiful water supplies and constitute a basis for effluent control rather than for subcategorization. Waste treatment procedures can be utilized in any geographical location.

A limitation in the availability of land space for constructing a waste treatment facility may in some cases affect the economic impact of a limitation. However, in-process controls and water conservation can be adopted to minimize the size and thus land space required for the treatment facility. Often, a compact treatment unit can easily handle wastewater if good in-process techniques are utilized to conserve raw materials and water.

Subcategorization Development

Upon initiation of the study of the battery manufacturing category, published literature and data generated in a preliminary study of the industry were reviewed, and a preliminary approach to subcategorization of the industry was defined. This approach was based on electrolytic couples (e.g. nickel-cadmium and silver oxide-zinc) and recognized battery types (e.g. carbon-zinc, alkaline manganese, and thermal cells). The weight of batteries produced was chosen as the production basis for data analysis. It provided the structure within which a detailed study of the industry was conducted, and was reflected in the data collection portfolio used to obtain data from all battery manufacturing facilities. In addition, sites selected for on-site data collection and wastewater sampling were chosen to provide representation of the significant electrolytic couples and battery types identified in the data collection portfolios. As discussed in Section III, the preliminary review of the category resulted in the identification of sixteen distinct electrolytic couples and battery types requiring consideration for effluent limitations and standards. A review of the completed dcp's returned by the industry revealed four additional battery types requiring study but did not initially result in any fundamental change in the approach to subcategorization. The initial battery types considered and additional battery types identified have been presented in Section III.

As the detailed study of the industry proceeded, however, it became apparent that the preliminary approach to subcategorization would not be adequate as a final framework for the development of effluent limitations and standards. It was determined that further breakdown of the original battery type subcategories would be required to encompass existing and possible process and product variations. The number of subcategories ultimately required using this approach was likely to approach two hundred. It was also found that this approach was likely to result in redundant regulations and possible confusion about applicability in some cases.

Review of dcp responses and on-site observations at a number of facilities revealed that there was substantial process diversity among plants producing a given battery type, and consequently little uniformity in wastewater generation and discharge. For most cell types, several different structures and production processes were identified for both anode and cathode, and it was observed that these could be combined into many variations. The data also revealed that not all plants performed all process operations on-site. Some battery manufacturing facilities produced cell electrodes or separators which were not assembled into batteries within the plant, and others purchased some or all of the components which were used in producing the finished batteries shipped from the plant. To reflect these

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differences in manufacturing processes it would have been necessary to divide the preliminary battery type subcategories into approximately 200 subcategories to accommodate those presently existing and into nearly 600 subcategories to encompass all of the obvious variations possible in new sources.

The data obtained from the industry also showed that most production operations are not separated by battery type. Manufacture of more than one battery type at a single location is common, and some production operations are commonly shared by different battery types. Raw material preparation, cell washes, and the manufacture of specific electrodes (most often the anode) are often commonly performed for the production of different battery types. Production schedules at some of these facilities make the association of production activity (and therefore wastewater discharge) in these operations with specific battery types difficult.

Many operations are intermittent and variable, and there is often a considerable lag between the preparation of raw materials and components, and the shipment of finished batteries. The redundant inclusion of production operations under several different battery types is undesirable in any case.

Subcategorization of the battery category was re-evaluated and redefined in the light of the industry characteristics discussed above. In the development of the final subcategorization approach, objectives were to:

1. encompass the significant variability observed in processes and products within battery manufacturing operations

2. select a subcategorization basis which yielded a managable number of subcategories for the promulgation of effluent limitations and standards

3. minimize redundancy in the regulation of specific process effluents

4. facilitate the determination of applicability of subcategory guidelines and standards to specific facilities

5. subcategorize so that, to the maximum extent possible, plants fall within a single subcategory

Available data show that where multiple cell types are produced, and especially where process operations are common to several types, the cells frequently have the same anode material. As a result, cell anode was considered as a subcategorization basis. Significant differences in wastewater volume and characteristics between plants

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producing zinc anode cells with alkaline electrolytes and Leclanche cells necessitated further subcategorization based on cell electrolyte. Subcategorization on these bases yielded eight subcategories: cadmium, calcium, lead, Leclanche, lithium, magnesium, nuclear, and zinc.

These subcategories preserve most recognized battery types within a single subcategory and greatly reduce the extent of redundancy in covering process operations. They also limit the number of plants producing batteries under more than one subcategory to thirteen. Recognized battery types which are split by this approach to subcategorization are carbon-zinc air cells which are manufactured with both alkaline and acidic electrolytes, and thermal batteries which are produced with calcium, lithium, and magnesium anodes. In both cases, however, significant variations in process water use and discharge exist within the preliminary battery type subcategories, and these are reflected in the breakdown resulting from anode based sub-categorization. In most cases where process operations are common to multiple battery types, they fall within a single subcategory. Where plants produce batteries in more than one subcategory, manufacturing processes are generally completely segregated.

Identification of these anode groups as subcategories for effluent limitations purposes was also favored by an examination of wastewater characteristics and waste treatment practices. In general, plants manufacturing batteries with a common anode reactant were observed to produce wastewater streams bearing the same major pollutants (e.g. zinc and mercury from zinc anode batteries, cadmium and nickel from cadmium anode batteries). As a result, treatment practices at these facilities show similarity.

A battery product within a subcategory is produced from a combination of anode manufacturing processes, cathode manufacturing processes and various ancillary operations such as assembly associated operations, and chemical powder production processes specific to battery manufacturing. Within each group (anode, cathode, ancillary) there are numerous manufacturing processes or production functions. These processes or functions generate or may generate independent wastewater streams with significant variations in wastewater characteristics. To obtain specific waste characteristics for which discharge allowances could be developed, the following approach was used (Figure IV-1, Page 89). Individual process waste streams (subelements) can be combined to obtain specific flow and waste characteristics for a manufacturing process or function with similar production characteristics which generates a process wastewater stream. Some manufacturing processes are not associated with any subelements, which will be discussed in Section V. Each significant battery manufacturing process or production function is called an element in this document. For example, in the cadmium subcategory a nickel cathode can be produced

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for a nickel-cadmium battery. One method of producing this cathode is by sintering nickel paste to a support structure and impregnating nickel salts within the pores of the sintered nickel. Several process waste streams can be associated with this manufacturing process such as, electrode rinse streams, spent solution streams, and air scrubber wastewater streams. All of these subelements are related to production of nickel impregnated cathodes, which is the element. Elements are combined or can be combined in various ways at specific facilities. At the element level, flows and pollutant characteristics can be related to production. Wastewater treatment however can be related to the specific subcategory which is considered the level of regulation. The detailed information which led to the adoption of the above subcategorization approach is presented in the discussion of process wastewater sources and characteristics in Section V of this document.

FINAL SUBCATEGORIES AND PRODUCTION NORMALIZING PARAMETERS

The final approach to subcategorization based on anode reactant material and electrolyte composition yielded eight subcategories:

.	Cadmium	.	Lithium
.	Calcium	.	Magnesium
.	Lead	.	Nuclear
.	Leclanche	.	Zinc

Specific elements within each subcategory and corresponding production normalizing parameters are summarized in Table IV-1 (Pages 90-91.). Selection of each production normalizing parameter is discussed within each subcategory discussion.

Cadmium Subcategory

This subcategory encompasses the manufacture of all batteries in which cadmium is the reactive anode material. Cadmium anodes for these cells are manufactured by three distinct processes and combined with either nickel, silver, or mercury cathodes. Nickel cathodes are produced by three different techniques, and silver and mercury cathodes by one each. In addition, eight ancillary process operations producing wastewater discharges were identified at plants in this subcategory. These process variations are all studied as individual elements for discharge limitations under this subcategory.

Consideration of the characteristics of each of the process elements discussed above results in the selection of production normalizing parameters. It was necessary to select specific production normalizing parameters for each process element because production activity areas in different elements was not found to be reliably related on a day-to-day basis at some facilities. The selected

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parameters, cadmium in the anode, active metal in the cathode, and total cell weight for ancillary operations (except for chemical powder production which is weight of metal in the powder produced or weight of metal used) correspond with the available production data and water use in the process operations addressed.

Use of active metal (cadmium, nickel, mercury or silver) as the production normalizing parameter for anode and cathode production operations reflects the fact that water use and discharge in these operations can be associated almost exclusively with the deposition, cleaning and formation (charging) of the active material. Similarly, the weight of metal in the chemical powder used or produced (cadmium, nickel, and silver) is the logical production normalizing parameter in considering discharges from chemical powder production. Other ancillary operations generally produce smaller volumes of process wastewater which are related to the total cell assembly or the overall level of production activity. The total weight of cadmium anode batteries produced was found to be the best production normalizing parameter for these discharges which could be readily derived from data available from most plants. The use of water in washing cells should correlate most closely with the cell surface area. Surface area data were not available, however, and total product weight was the best available approximation to it.

Alternatives to the production normalizing parameters discussed above were evaluated and include:

1. the use of battery weight for all operations

2. electrode surface area

3. total electrode weight

4. battery electrical capacity

5. number of employees

Total battery weight was found to be readily available from most manufacturers, and was initially considered a logical choice for the production normalizing parameter for these plants. This parameter would have allowed the use of a single parameter for all waste sources in a plant, potentially simplifying the application and enforcement of effluent limitations. Following plant visits, it became evident, however, that production patterns at some facilities would render this production normalizing parameters inapplicable, and that production variations resulted in significant variability between production activity in the major wastewater producing operations and the weight of batteries ultimately shipped. Some plants were identified which produced cell electrodes but did not produce finished batteries, and

others indicated the production of finished batteries from electrodes processed at other locations. For such facilities the battery weight production normalizing parameter is clearly inapplicable to the determination of wastewater discharges from electrode manufacturing operations. Batteries are produced in this subcategory for a wide range of applications and in many different configurations. As a result, the ratio of battery weight to the weight of reactive materials contained by the battery varies significantly. Since the most significant water use and discharge is associated with the reactive materials, the use of battery weight as a production normalizing parameter for all operations would result in non-uniform application of effluent limitations and standards to plants in this subcategory.

Since most of the wastewater discharge volume associated with electrode production results from depositing materials on or removing impurities from electrode surfaces, electrode surface area was considered a possible choice as the production normalizing parameter for these operations. Significant difficulty is encountered in defining the surface area, however, and data were not available. The difficulty results from the fact that the electrodes generally have significant porosity and irregular surfaces, and it is the total wetted surface rather than the simple projected area which determines the volume of wastewater generated. Since this area could not be readily determined, electrode surface areas were not chosen as the production normalizing parameters for these operations.

Total electrode weights were found to be less desirable than active material weights because the use of process water is involved primarily with the active materials. Since most electrodes produced in this subcategory include non-reactive support and current collecting structures which account for varying fractions of the total electrode weight, the relationship between electrode weight and wastewater volume is less consistent than that between wastewater and the weight of reactive materials in the electrode.

Battery electrical capacity should, in concept, correspond well with those characteristics of cell electrodes most closely associated with process water use and discharge during manufacture. The electrical capacity of cells is determined by the mass of reactive materials present, and the processing of reactive materials is the major source of process wastewater for most cell types. It was not, however, considered a viable production normalizing parameter for use in this study because electrical capacity data were not obtained.

Because the degree of process automation at battery manufacturing plants was observed to vary, the number of production employees was not found to be generally suitable as a production normalizing parameter. While the number of employees would be a suitable basis

for limiting discharges from employee showers and hand washes, battery weight was chosen instead to achieve uniformity with other ancillary wastewater sources and minimize the number of production normalizing parameters to be applied.

Calcium Subcategory

Batteries included in this subcategory use calcium as the reactive anode material. At present, only thermal batteries, in which a fused mixture of potassium chloride and lithium chloride serves as the electrolyte and calcium chromate as the cathode depolarizer, are produced in this subcategory. While many different configurations of these batteries are manufactured, most production can be accomplished without the use of process water. Significant elements in this subcategory include anode manufacture (vapor-deposited or fabricated calcium), cathode production (calcium chromate), and one ancillary element for the manufacture of reactive material used to heat the cell to its operating temperature upon activation (heating component production).

The production normalizing parameter selected for the thermal cell activator is the combined weight of reactive materials used in production of the heating component (usually barium chromate and zirconium). The selection of a production normalizing parameter specific to heating component production is necessary because the amount of activator material contained in thermal cells is highly variable; hence total battery production weight is not meaningfully related to wastewater generation and discharge. The production normalizing parameter selected for the anode manufacture is weight of calcium used, and for the cathode is weight of reactive cathode material in the cells.

Lead Subcategory

Two basic electrochemical systems are included in this subcategory: lead acid reserve or lead; and lead-acid storage or lead-lead peroxide. As discussed in Section V for the manufacture of lead acid reserve cells, lead electroplated on a steel carrier is produced, which is not considered part of battery manufacturing. Lead acid storage batteries all use the lead-lead peroxide electrolytic couple, but differences in battery type and manufacturing processes require careful examination of production normalizing factors. Some of the significant variations include:

.   Full line manufacture (plates produced on-site)

.   Assembly using green plates (formation on-site)

.   Assembly using formed plates

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- Leady Oxide Production

  Purchased oxide
  On site production
      Ball Mill process
      Barton process

- Plate Grids

  Antimonial alloy (cast)
  Pure lead (cast, punched, or rolled)
  Calcium alloy (cast, punched, or rolled)

- Plate Curing

  With steam
  Without steam

- Plate Formation (Charging)

  <u>Closed Formation</u> (electrodes assembled in battery case)

      Single fill-single charge
      Double fill - double charge
      Double fill - single charge
      Acid dumped after charge - no refill (damp batteries)

  <u>Open Formation</u>

      Electrodes formed, rinsed, and dried prior to assembly
      (dehydrated batteries)
      Plates formed prior to assembly into batteries

- Electrolyte

  Immobilized
  Liquid

- Case

  Sealed
  Vented

- Battery Wash

  None
  With water only
  With detergent

.   Configuration

        Cylindrical
        Rectangular

.   Separators

        Rubber
        Paper-Phenolic
        Vinyl

Among these variations, the distinction between full line manufacture and assembly, and variations in plate curing and formation and battery wash operations were observed to have a significant effect on the volume and treatability of process wastewater. To adequately reflect the combinations of these variables observed within the industry, the subcategory was subdivided on the basis of specific process operations.

The total lead weight (including the weight of alloying elements in lead grid alloys) used in batteries produced was chosen as the production normalizing parameter for all process elements for which discharge allowances are provided in this subcategory. As discussed for the cadmium subcategory, total battery weight, electrode surface area, total electrode weights, battery electrical capacity, and number of employees were considered as alternatives to the selected production normalizing parameter. The weight of lead consumed in battery manufacture was chosen in preference to total battery weight because total battery weight is subject to variations resulting from differences in the ratio of case weight to the weight of active material. Case weight is not directly related to wastewater generation. Further, battery weight is not applicable where plates are shipped for use at other locations. Total electrode weights were not generally reported by plants in this subcategory and, further, are subject to variation due to the degree of hydration and state of charge of the electrode. Therefore, the weight of lead was found to provide a more available and reproducible basis for effluent limitations and standards. Factors which led to the rejection of electrode surface area, battery electrical capacity, and number of employees as production normalizing parameters for the lead subcategory are the same as those discussed for the cadmium subcategory.

Leclanche Subcategory

The Leclanche dry cell uses an amalgamated zinc anode, a carbon cathode with manganese dioxide depolarizer, and ammonium chloride and zinc chloride electrolyte. Batteries manufactured in this subcategory use zinc anodes and acid chloride electrolytes. Most also use

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manganese dioxide as the cell depolarizer although cells using atmospheric oxygen and silver chloride depolarizers are also included in this subcategory. All of these cells are produced in manufacturing processes in which water use is limited, and the volume of process wastewater produced is small.

Significant product and process variations within the subcategory include:

Anode Structure
    Sheet Zinc - stamped
    Sheet zinc formed as cell container
    Sheet Zinc - Fabricated
    Powdered zinc deposited on substrate

Cathode Material
    Manganese-dioxide and carbon
    Silver chloride

Cell Separator
Paste
        Cooked
        Uncooked
Pasted Paper
        With Mercury
        Without Mercury

Amalgamation
    Mercury in electrolyte
    Mercury in separator

The most significant elements in this subcategory include the separator processes. Pasted paper can be manufactured at the battery facility or purchased. Paper which contains mercury in the paste is included under battery manufacturing. The production normalizing parameter for this operation is the weight of dry paste material, which can easily be related to this process. For cooked paste and uncooked paste separators, the weight of cells produced is the selected production normalizing parameter which can be related to these processes. Cell weight was supplied by most plants. Weight of cells produced can also be related to all other process operations in this subcategory such as zinc powder production, cathode production, and equipment and area cleanup operations. The production of stamped, drawn or fabricated zinc anodes is not considered under battery manufacturing.

Alternative production normalizing parameters including electrode surface area, separator paper consumption and electrode raw materials were also considered. Electrode surface areas could be readily

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determined for those anodes prepared from sheet zinc, but do not correspond to the production activities which might result in battery manufacturing process wastewater. As discussed for other subcategories, surface areas are not readily determined for cell cathodes and for anodes prepared using powdered zinc. In addition, there is little evident relationship between process water use and electrode surface area in this subcategory. The consumption of separator paper is a conceivable basis for the limitation of dis-charges from pasted paper separator production, or from the manu-facture of cells containing pasted paper separators. It is subject to variability, however, due to the varying amounts of paste applied, and also does not apply to batteries manufactured with other separators. Electrode materials are frequently used as structural parts of Leclanche cells and the weight of zinc used is not necessarily stoichiometrically related to the other battery reactants or to water use in process steps.

Lithium Subcategory

This subcategory encompasses the manufacture of several battery types in which lithium is the anode reactant. Depolarizers used in these batteries include iodine, lead iodide, sulfur dioxide, thionyl chloride, iron disulfide, titanium disulfide, and lithium perchlorate. Electrolytes used within this subcategory include liquid organic compounds such as acetonitrile and methyl formate, solid organic compounds such as poly-2-vinyl pyridine, solid inorganic salts, and fused inorganic salts (in thermal batteries). None of the cells reported to be in current manufacture uses an aqueous electrolyte. Thermal batteries produced with lithium anodes include heat generation component production which was discussed under the calcium subcategory.

Anode production for this subcategory includes formed and stamped lithium metal. This operation is considered unique to battery manufacturing. Process wastewater might result from air scrubbers and therefore the weight of lithium is selected as the production normalizing parameter. For those processes associated with cathode production operations (including addition of the depolarizer to the cell electrolyte), the weight of cathode reactant in the cells has been chosen as the production normalizing parameter. This information was available from plants manufacturing these batteries, and is directly related to the production activities for which limitations and standards can be developed. For ancillary operations, two distinct production normalizing parameters are chosen. As discussed for calcium anode battery manufacture, the production normalizing parameter for discharges from heating component manufacture is the total weight of heating component reactive materials. For all other ancillary operations, the production normalizing parameter is the weight of cells produced. These operations are either directly

involved with the complete cell assembly (testing and cell wash) or with a process by product (lithium scrap disposal). For those operations related to the total cell assembly, the total weight of batteries produced is a sound basis for predicting water use and discharge.

Magnesium Subcategory

This subcategory, addressing cells with magnesium anodes, include magnesium-carbon batteries in which the depolarizer is manganese dioxide, magnesium anode thermal batteries in which the depolarizer is vanadium pentoxide, magnesium reserve cells using copper chloride, silver chloride, or lead chloride depolarizers, and ammonia activated cells in which meta-dinitrobenzene serves as the depolarizer. Cell electrolytes include aqueous solutions of magnesium perchlorate, or magnesium bromide, sea water (added to reserve cells at the time of activation), fused mixtures of potassium chloride and lithium chloride, and ammonium thiocyanate (dissolved in ammonia to activate ammonia activated cells). Magnesium anodes for many of these cells are protected from corrosion during storage by chromate coatings which may be on the magnesium when it is obtained by the battery plant or may be applied at the battery manufacturing site.

Production normalizing parameters were selected on the same general basis as discussed for other subcategories. Magnesium anode production which includes sheet magnesium that is stamped, formed or fabricated and magnesium powder related processes are not included under battery manufacturing. Depolarizer weight is the production normalizing parameter for depolarizer production. Heating component production is limited on the basis of the weight of reactants as discussed previously for the calcium anode subcategory, and the weight of batteries produced is selected as the production normalizing parameter for cell testing and cell separator processing operations, floor area maintenance, and assembly area air scrubbers.

Nuclear Subcategory

Commercial nuclear batteries were produced primarily for use in heart pacemakers. Production of these batteries has ceased with the increase in production of lithium batteries. Although wastewater was generated by the manufacture of nuclear batteries, the subcategory will not be further defined, and production normalizing parameters will not be examined until production again resumes.

Zinc Subcategory

Batteries produced in this subcategory have an amalgamated zinc anode and a sodium or potassium hydroxide electrolyte. Cells using ten different depolarizer combinations are presently produced within the

subcategory in a wide variety of cell configurations and sizes. Zinc anodes for these cells are produced in seven distinct processes, but anodes produced by each process are typically combined with several different types of cathodes, and anodes produced by two or more different processes are commonly used with a given depolarizer.

The weight of reactive material contained in the electrode was found to be the best production normalizing parameter for anode and cathode manufacturing processes. For most ancillary operations, which are usually associated with cell assemblies or with general plant production activity, the production normalizing parameter is the total weight of batteries produced. For one ancillary operation, the etching of silver foil used as a substrate for zinc anodes, the weight of silver foil used for etching is chosen as the production normalizing parameter. The use of this parameter rather than total battery weight is necessary because not all batteries at any given plant are produced using etched foil. The volume of wastewater from this operation will therefore not be directly related to the total product weight. For silver powder production, the weight of silver powder produced is used as the production normalizing parameter, and for silver peroxide powder production, the weight of silver powder used is the production normalizing parameter.

Alternatives to the selected production normalizing parameters which were considered include the use of total battery weight for all operations, electrode surface area, total electrode weight, battery electrical capacity, and the number of production employees. These were evaluated and rejected in favor of the selected parameters on the basis of factors very similar to those discussed for the cadmium anode subcategory. Electrode manufacturing processes are common to multiple battery types at several plants in this subcategory, with the fraction of total cell weight comprising active material in each electrode unique to each cell type. Further, electrode production (or active material processing) may not be scheduled concurrently with cell assembly for all products, and may be performed at one facility for cells assembled at another site. As a result, it is necessary that discharges from electrode production be limited on the basis of a parameter unique to the electrode itself, and total product weight is not a useful discharge limiting factor for these operations. Electrode surface area was not chosen as the production normalizing parameter because, as discussed previously, it is not available and not readily determined. Because some electrodes include non-reactive materials for support and current collection and others (with the same reactants) do not, total electrode weights do not correspond as well to water used in processing active materials as do the weights of active materials themselves. As discussed previously, total electrical capacity has potential as a production normalizing parameter but supporting data is not presently available. The number

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of employees does not correlate well with process water use and discharge.

OPERATIONS COVERED UNDER OTHER CATEGORIES

Many battery plants perform processes on-site which are not unique to battery manufacturing and which are addressed in effluent limitations and standards for other industrial categories. These have been identified in Table IV-2 (Page 92) and are discussed with reference to the lead subcategory and in general for the other subcategories. Specific operations are discussed in Section V.

Lead Subcategory

Plants producing batteries within the lead subcategory practice a number of processes included in other industrial categories. Most facilities produce electrode grids on-site. These are most often cast from lead (and lead alloys), a metal casting operation, but may also be rolled or stamped from pure or alloy lead in metal forming operations. Some lead anode battery plants also produce rubber or plastic battery cases on-site.

The production of lead oxide at battery plants is a unique operation yielding a "leady oxide" distinct from lead oxide produced under inorganic chemical production. It is included under the battery manufacturing category for effluent limitations.

Other Subcategories

Battery manufacturing plants in other subcategories have been observed to employ a number of manufacturing processes including: metal forming and shaping, metallurgical plant operations, metal plating, paper pasting processes (without mercury) and inorganic chemicals preparation.

These manufacturing operations are not considered as battery manufacturing operations. Metal forming and shaping operations including deburring and cleaning are involved in the production of anodes (which may also serve as the cell container), and various cell contacts, covers and jackets. Several battery plants report the preparation of metal alloys or the operation of secondary metals recovery operations. A number of battery manufacturing processes involve plating or chromating metals on battery parts or assembled battery cases. Some facilities paste paper with flour and starch without using mercury. Inorganic chemicals not specific to battery manufacturing are often purchased, but may be produced on-site. None of these operations are addressed in the development of battery manufacturing effluent limitations and standards.

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FIGURE IV-1
SUMMARY OF CATEGORY ANALYSIS

TABLE IV-1

SUBCATEGORY ELEMENTS AND PRODUCTION NORMALIZING PARAMETERS (PNP)

SUBCATEGORY		ELEMENT	PNP	SUBCATEGORY		ELEMENT	PNP
Cadmium	Anodes	Pasted And Pressed Powder Electrodeposited Impregnated	Weight of Cadmium in Anode	Lead	Anodes and Cathodes	Electroplated Lead	NA
	Cathodes	Silver Powder Pressed	Weight of Silver in Cathode			Leady Oxide Production Paste Preparation and Application Curing Closed Formation (In Case) Single Fill Double Fill Fill and Dump Open Formation (Out of Case) Dehydrated Wet	Total Weight of Lead Used
		Mercuric Oxide Powder Pressed	Weight of Mercury in Cathode				
		Nickel Pasted and Pressed Powder Nickel Electrodeposited Nickel Impregnated	Weight of Applied Nickel				
	Ancillary	Cell Wash Electrolyte Preparation Floor and Equipment Wash	Weight of Cell Produced		Ancillary	Battery Wash Floor Wash Sinks and Shower Battery Repair	
		Employee Wash Cadmium Powder Production Cadmium Hydroxide Production	Weight of Cadmium Used	Leclanche	Anodes	Zinc Powder	Weight of Cells Produced
		Nickel Hydroxide Production	Weight of Nickel Used			Sheet zinc stamped drawn fabricated	NA
		Silver Powder Production	Weight of Silver Used		Cathodes	Manganese Dioxide-electrolyte with mercury Manganese Dioxide-electrolyte without mercury Manganese Dioxide-gelled electrolyte with mercury Pasted Manganese Dioxide Carbon Silver Chloride	Weight of Cells Produced
Calcium	Anodes	Vapor Deposited Fabricated	Weight of Calcium Used				
	Cathodes	Calcium Chromate Tungstic Oxide Potassium Dichromate	Weight of Reactive Material		Ancillary	Separator Cooked Paste Separator Uncooked Paste	Weight of Cells Produced
	Ancillary	Heat Generation Component Production	Total Weight of Reactive Materials			Separator Pasted Paper with mercury	Weight of Dry Pasted Material
						Separator Pasted Paper w/o mercury	NA
						Equipment and Area Cleanup	Weight of Cells Produced

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TABLE IV-1

SUBCATEGORY ELEMENTS AND PRODUCTION NORMALIZING PARAMETERS (PNP)

SUBCATEGORY		ELEMENT	PNP	SUBCATEGORY		ELEMENT	PNP

Lithium	Anodes	Formed & Stamped	Weight of Lithium	Zinc	Anodes	Cast or Fabricated
						Wet Amalgamated Powder
						Gell Amalgam
						Dry Amalgamated Powder
						Pasted and Pressed Zinc
						  Oxide Powder
						Pasted and Pressed Zinc Oxide
						  Powder, Reduced
							Weight of Zinc
							Used

	Cathodes	Sulfur Dioxide Iodine Iron Disulfide Lithium Perchlorate Titanium Disulfide Thionyl Chloride Lead Iodide	Weight of Reactive Material			Electrodeposited	Weight of Deposited Zinc
	Ancillary	Heat Generation Component Production	Weight of Reactive Materials		Cathodes	Porous Carbon	Weight of Carbon
		Lithium Scrap Disposal Testing	Weight of Cells Produced			Manganese Dioxide Carbon	Weight of Manganese Dioxide

						Mercuric Oxide (and
						  Manganese Dioxide-
						  Carbon)
							Weight of Mercury

Magnesium	Anodes	Sheet Magnesium
		  stamped
		  formed
		  fabricated
			NA			Mercuric Oxide-
						  Cadmium Oxide
							Weight of Mercury
							and Cadmium

		Magnesium Powder	Weight of Magnesium
			Used
						Silver Powder Pressed
						Silver Powder Pressed
						  and Electrolytically
						  Oxidized
						Silver Oxide
						  Powder Thermally
						  Reduced or Sintered,
						  Electrolytically
						  Formed
						Silver Oxide Powder
						Silver Peroxide Powder
							Weight of Applied
							Silver

	Cathodes	Silver Chloride-
		  Surface Reduced
		Silver Chloride-
		  Electrolytic
		Copper Chloride
		Lead Chloride
		Vanadium Pentoxide
		Carbon
		M-Dinitrobenzene
			Weight of Depolarizer
			Material
						Nickel Impregnated and
						  Formed
							Weight of Applied
							Nickel

	Ancillary	Heat Generation Component
		  Production
			Weight of Reactive
			Materials
					Ancillary	Cell Wash
						Electrolyte Preparation
						Mandatory Employee
						  Wash
						Reject Cell Handling
						Floor Wash
						Equipment Wash
							Weight of Cells
							Produced

		Testing Separator Processing Floor Wash Scrubbers	Weight of Cells Produced			Silver Etch Silver Peroxide Production	Weight of Silver Used
						Silver Powder Production	Weight of Silver Powder Produced

NA- Not Applicable to Battery Manufacturing Category

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TABLE IV-2

OPERATIONS AT BATTERY PLANTS INCLUDED
IN OTHER INDUSTRIAL CATEGORIES
(PARTIAL LISTING)

Lead Alloy Grid Casting and Forming
Plastic and Rubber Battery Case Manufacture
Forming Cell Containers and Components (Including Zinc and
    Magnesium Can Anodes)
Cleaning and Deburring Formed Cell Components
Retorting, Smelting and Alloying Metals
Metal Plating (Includes Chromating of Zinc and Magnesium Cans)
Inorganic Chemical Production (Not Specific to Battery Manufacturing)
Pasted Paper Manufacture (Without Mercury)

SECTION V

WATER USE AND WASTEWATER CHARACTERIZATION

This section describes the collection, analysis, and characterization of data which form the basis for effluent limitations and standards for the battery manufacturing category, and presents the results of these efforts. Data were collected from a variety of published sources, from previous studies of battery manufacturing, through data requests mailed to all known battery manufacturers, and through on-site data collection and sampling at selected facilities. Data analysis began with an investigation of the total category, the manufacturing processes practiced, the raw materials used, the process water used and the wastewater generated. This led to the subcategorization and production normalizing parameters selected and discussed in detail in Section IV. Further analysis included wastewater sample collection and characterization of the wastewater streams within each subcategory. Specific discussions of data analysis and presentation of results for each subcategory follows a general description of data collection and analysis approach.

DATA COLLECTION AND ANALYSIS

The sources of data used in this study have been discussed in Section III. Published literature and previous studies of battery manufacturing provided a basis for initial data collection efforts and general background for the evaluation of data from specific plants. Data collection portfolios (dcp's) sent to all battery manufacturing companies provided the most complete and detailed description of the category which could be obtained. They were used to develop category and subcategory data summaries and were the primary basis for the selection of plants for on-site sampling and data collection. Data from plant visits provided characterization of raw and treated wastewater streams within the category and allowed in-depth evaluation of the impact of product and process variations on wastewater characteristics and treatability.

Data analysis proceeded concurrently with data collection and provided guidance for the data collection effort. Initially, a review and analysis of the available information from published sources and previous studies was used as the basis for developing the dcp used to obtain information about battery manufacturing facilities, and as a preliminary data base structure within which analysis of the completed dcp's could proceed. This included the definition of preliminary subcategories within the battery manufacturing category which were expected to differ significantly in manufacturing processes and wastewater discharge characteristics, and which consequently should be represented in on-site data collection and wastewater sampling.

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Specific sites for sampling were selected on the basis of data obtained in completed dcp's. During one sampling visit for each subcategory screening samples were obtained which were analyzed for all priority pollutants and other selected parameters. The results of these screening analyses together with data obtained in completed dcp's were evaluated to select significant pollutant parameters for each subcategory whose presence and concentrations were verified by analysis in all subsequent wastewater samples.

Data Collection Portfolio

The data collection portfolio (dcp) was used to obtain information about production, manufacturing processes, raw materials, water use, wastewater discharge and treatment, and effluent quality from battery manufacturers. The dcp was comprised of two segments, the first of which requested information about manufacturing processes, water use, wastewater discharge, and waste treatment practices in addition to analysis results characterizing process wastewater. The second segment of the dcp requested information specifically pertaining to the presence of priority pollutants in process wastewater from the facility. Because many battery manufacturing plants, particularly lead acid battery manufacturers operate on-site casting facilities, a dcp addressing casting operations was included with the battery manufacturing dcp. Process wastewater discharges from casting are not regulated as part of the battery manufacturing category.

Developed during 1977, the dcp requested data for the year 1976 which was the last full year for which production information was expected to be available. Mailing of the dcp, however, was in 1978. Consequently, a few plants provided information for the years 1977 and 1978 rather than 1976 as requested in the dcp. All of the data received were used in characterizing the industry.

The dcp's were mailed to all known companies manufacturing batteries as determined from SIC code listings compiled by Dun and Bradstreet Inc., membership in battery industry trade associations, listings in the Thomas Register, and lists of battery manufacturers compiled during previous EPA studies. These lists, which sometimes included battery distributors and wholesalers as well as manufacturers, and also included both corporate headquarters and individual plant locations, were screened to identify corporate headquarters for companies which manufacture batteries and to eliminate distributors and wholesalers. Dcp's were mailed to each corporate headquarters, and a separate response was requested for each battery manufacturing plant operated by the corporation. As a result of dcp distribution and follow-up, responses were received confirming battery manufacture by 133 companies operating 235 manufacturing facilities, of which currently there are about 132 companies operating about 230

facilities. Due to the dynamic nature of battery manufacturing, these numbers may vary from month to month.

Specific information requested in the dcp's was determined on the basis of an analysis of data available from published sources and previous EPA studies of the battery manufacturing category, and consideration of data requirements for the promulgation of effluent limitations and standards. Basic data required to identify the facility and facilitate follow-up contacts included the name and address of the plant and corporate headquarters, and the names and telephone numbers of contacts for further information. Description of wastewater treatment practices and data on water use and wastewater discharge as well as wastewater characteristics fundamental to the development of effluent limitations were requested. Since the evaluation of these data is enhanced by a knowledge of water source, discharge destination, and the type of discharge regulations to which the plant is subject, the dcp's included requests for this information as well. In recognition of the fact that analysis for many of the priority pollutants had not been performed at most facilities, the dcp included the request for an indication for each priority pollutant of whether it was known or believed to be present in or absent from process wastewater from the facility.

The analysis of information prior to development of the dcp indicated that wastewater volumes and characteristics varied significantly among different battery types as defined by chemical reactants and electrolyte employed, and that the raw materials used in battery manufacture constituted potential sources of significant pollutants. In addition, it was ascertained that batteries of a given type are commonly produced in a variety of sizes, shapes, and electrical capacities. The available data also indicated the possibility of significant process variations differing in wastewater discharge characteristics.

As a result of these considerations, the dcp was developed to obtain identification of the specific battery types manufactured and the raw materials used for each type. Production volume was requested in terms of the total weight of each battery type produced since this was expected to be more meaningful in terms of wastewater discharge than the number of units manufactured. Production information was requested both in terms of total annual production and in terms of production rate (lbs/hr) to provide correspondence with wastewater flow rates which were obtained in gallons per hour. A complete description of the manufacturing process for each battery type including designation of points of water use and discharge and of raw material usage as well as specification of water flow rates was also requested. Finally, chemical characteristics of each process wastewater stream were requested.

Of the 235 confirmed battery manufacturing facilities, all but ten returned either a completed dcp or a letter providing available information submitted in lieu of the dcp. This level of response was achieved through follow-up telephone and written contacts after mailing of the original data requests. Follow-up contacts indicated that most plants which did not provide a written response were very small and together comprised a negligible fraction of the industry.

The quality of the responses obtained varied significantly, however. While most facilities were able to provide most of the information requested in the dcp, a few (generally small) plants indicated that the available information was limited to the plant name and location, product, and number of employees. These facilities usually reported that they discharged no process wastewater. There was also considerable variability in the process descriptions provided. Information was asked for descriptions of all process operations including those that generated process wastewater. Over 50 percent of the lead subcategory plants and approximately 40 percent of the other plants submitting dcp's did not supply discharge flows for some specific process operations, indicating that process wastewater was not generated for these specific processes. In some additional dcp's specific process flow rates were found to conflict with water use and discharge rates reported elsewhere in the dcp. Nonetheless, sufficient specific process flow information was provided in the dcp's to provide flow rate characterization of most process elements for each subcategory. These data were augmented by data from plant visits and where appropriate by information gained in follow-up telephone and written contacts with selected facilities. Raw waste chemical analysis were almost universally absent from the dcp's and had to be developed almost entirely from sampling at visited plants and from data developed in previous EPA studies.

When received, each dcp was reviewed to determine plant products, manufacturing processes, wastewater treatment and control practices, and effluent quality (if available). This review provided the basis for selection of sites for plant visits for on-site data collection and sampling. Subsequently, selected data contained in each portfolio was entered into a computer data base which was used to rapidly identify plants with specific characteristics (e.g. specific products, process operations, or waste treatment processes), and to retrieve basic data for these facilities. Review of the complete dcp data base together with data collected on-site at specific plants formed the basis for definition of the final industry subcategorization as described in Section IV. The dcp data base was then used to define production normalized process wastewater flows for each distinct process operation or function within each subcategory. It also was the primary source for the identification of wastewater treatment technologies and in-process control techniques presently employed

within each subcategory and provided information about the effectiveness of many of these.

Plant Visits and Sampling

A total of 40 battery manufacturing facilities were visited as part of the data collection effort. At all of the visited plants information was obtained about the manufacturing process, raw materials, process wastewater sources (if any), and wastewater treatment and control practices. At nineteen plants, wastewater samples were also collected.

Because of the large number of pollutants to be investigated, a two stage approach to sampling was used to ensure the most effective use of program resources. Initially, influent water, raw wastewater, and treated effluent samples obtained from a single plant in each subcategory were analyzed for all of the pollutants under consideration. Results of this screening analysis were used to select a smaller list of parameters found to be potentially significant for the subcategory. The significance of the parameters was verified by analysis in all remaining wastewater samples from plants in the subcategory. This screening-verification approach allowed both investigation of a large number of pollutants and in-depth characterization of individual process wastetwater streams without incurring prohibitive costs.

Sampling and Analysis Procedures

Sites for visits to battery manufacturing facilities were initially selected based on a review of the dcp's. Somewhat different criteria were applied to the selection of sites for screening and verification sampling. For screening the most important basis for selection was that process wastewater generation at the plant be representative of the subcategory, ie. that manufacturing processes, raw materials, and products be similar to those at other sites. For screening, sampling was done on the basis of the battery type subcategorization. Preference was given to plants with multiple products or processes. For verification sampling, wastewater control and treatment practices assumed major importance with emphasis on the selection of plants which demonstrated effective pollutant reductions as determined by effluent volume or quality. For some subcategories, however, the number of plants was sufficiently small that production in the sub-category and generation of wastewater became sufficient grounds for selection regardless of wastewater treatment and control practices.

Each site selected as a potential sampling site was initially contacted by telephone to confirm and expand the dcp information and to ascertain the degree of cooperation which the plant would provide. The dcp for the plant was then reviewed to identify specific process

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wastewater samples to be obtained to characterize process raw waste streams and wastewater treatment performance and also data required in addition to that provided in the dcp. The plant was then visited for one day to determine specific sampling locations and collect additional information. In some cases, it was determined during this preliminary visit that existing wastewater plumbing at the plant would not permit meaningful characterization of battery manufacturing process wastewater, and plans for sampling the site were discontinued. Where sampling was performed, a detailed sampling plan identifying sampling locations, flow measurement techniques, sampling schedules (where flows were not continuous), and background data to be developed during sampling was developed on the basis of the preliminary plant visit.

Wastewater samples collected at most sites were selected to provide a characterization of process wastewater from each distinct process operation, of the total process waste stream, and of the effluent from wastewater treatment. Multiple wastewater streams from a single process operation or unit, for example individual stages of a series rinse, were generally flow proportionally composited and were not sampled separately. In some cases, wastewater flow patterns at specific plants did not allow separate sampling of some process waste streams, and only samples combining wastes from two or more process operations could be obtained. Where possible, chemical characteristics of these individual waste streams were determined by mass balance calculations from the analyses of samples of other contributing waste streams and of combined streams. In general, process wastewater samples were obtained prior to any treatment, settling in sumps, dilution, or mixing which would change their characteristics. Where this was not possible, sampling conditions were carefully noted in the documentation of the sampling visit and considered in evaluation of the sampling results.

In all 257 raw waste samples were obtained characterizing 75 distinct wastewater sources associated with 37 different battery manufacturing process operations. In addition, 22 samples were obtained from plant water supplies. Samples were also obtained for analysis which characterized either wastewater streams from sources other than battery manufacturing which were combined for treatment with battery manufacturing wastes, or wastewater at intermediate points in treatment systems incorporating several operations.

Screening samples were obtained to characterize the total process wastewater before and after treatment. As a result, only the combined raw waste stream and total process effluent were sampled for screening. At plants where a single combined raw waste stream or treated effluent did not exist, samples from discrete waste sources were flow proportionally composited to represent the total waste streams for screening.

Samples were collected at each site on three successive days. Except where production or wastewater discharge patterns precluded it, 24 hour flow proportioned composite samples were obtained. Composite samples were prepared either by using continuously operating automatic samplers or by compositing grab samples obtained manually once each hour. For batch operations composites were prepared by compositing grab samples from each batch. Wastewater flow rates, pH, and temperature were measured at each sampling point on an hourly basis or for batch operations, when each sample was taken. At the end of each sampling day, aliquots of each composite sample were taken for analysis for organic priority pollutants, metals, and for TSS, cyanide, ammonia and oil and grease. Grab samples were taken for analysis for volatile organic compounds and for total phenols because these parameters would not remain stable during compositing. Composite samples were kept on ice during compositing, shipment, and holding until analyzed. Analysis for metals was by plasma arc spectrograph for screening and by atomic absorption for verification analysis. Analysis for organic priority pollutants was performed by gas chromatograph-mass spectrometer for screening and some verification analysis, and by gas chromatograph alone for others. Both sampling and sample analysis were performed in conformance with a protocol developed by the EPA.

Screening Analysis Results

The results of screening analysis for each subcategory are presented in Tables V-1 through V-7 (Pages 228 - 261) which also show the extent to which each pollutant was reported in dcp's to be known or believed present in process wastewater from plants in the subcategory. In the tables ND indicates that the pollutant was not detected, and for organic pollutants, * and ** indicate detection at levels below quantifiable limits. For most organics, * is used to indicate equal to or less than 0.01 mg/l. For pesticides (pollutants 89-105), ** indicates detection equal to or less than a quantifiable limit of 0.005 mg/l. For metals, the use of < indicates that the pollutant was not detected by analysis with a detection limit as shown. NA indicates that analysis for the specific pollutant was not performed. For certain pollutant parameter pairs, concentrations cannot be separated by the type of analysis used. Therefore pollutants numbered 72 and 76 will have the same concentration reported as well as 78 and 81, and 74 and 75. Dioxin, alkyl epoxides, and xylenes, were not analyzed in any samples because established analytical procedures or standards were not available. Analytical procedures were developed for asbestos sampling after screening had already occurred. The sampling results reported for this pollutant are not necessarily from the same plant which was used for screening. For selected plants asbestos self-sampling kits along with established protocol were sent for influent, raw wastewater and effluent samples for each subcategory. No analyses for non-volatile organic pollutants were

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performed on one of the zinc subcategory screening samples due to loss of the sample in shipment. Two sets of screening data are presented for the zinc subcategory. Two plants in this subcategory were screened because screening was initially performed on the basis of the preliminary product type subcategories. This fact also resulted in some instances where not all samples in a given subcategory were analyzed for the same set of verification parameters as will be discussed later.

Selection Of Verification Parameters

Verification parameters for each subcategory were selected based on screening analysis results, occurrence of the pollutants in process waste streams as reported in dcp's, and a technical evaluation of manufacturing processes and raw materials used within each subcategory. Criteria for selection included:

1. Occurrence of the pollutant in process wastewater from the subcategory may be anticipated based on its presence in, or use, as a raw material or process chemical. Also the pollutant was indicated in dcp priority pollutant segments as being known or believed to be present in process wastewaters.
2. The pollutant was found to be present in screening analysis. If the presence of the pollutant was at or below the quantifiable limit, the other criteria were used to determine if selection of the parameter was justified.
3. The observed concentrations are environmentally significant. This included an analysis of the proposed ambient water quality criteria concentrations presently available. Also included was an evaluation of concentrations detected in blank, influent, and effluent samples.

The criteria was used for the final selection of all verification parameters, which included both toxic and conventional pollutant parameters. An examination was made of all nonconventional pollutants detected at screening and several were also selected as verification parameters. Specific discussion of the selection of verification parameters for each subcategory is presented in the following paragraphs.

Cadmium Subcategory. Based on screening analysis and evaluation of this subcategory, sixteen pollutant parameters were selected for further analysis. The sixteen are:

44	methylene chloride	126	silver (for silver cathodes only)
87	trichloroethylene	128	zinc
118	cadmium		ammonia
119	chromium		cobalt
121	cyanide		phenols (4AAP)

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122  lead                          oil and grease
123  mercury                       TSS
124  nickel                        pH
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The organic pollutants benzene, dichlorobromomethane and bis(2-ethylhexyl)phthalate were all detected in screening samples at concentrations below the quantifiable limit and were not selected for verification because there was no clear relationship between these pollutants and manufacturing processes in this subcategory. Chloroform was also detected in screening but was attributable to influent water and was therefore not selected for verification sampling. Toluene was observed at concentrations as high as 0.025 mg/l but was not chosen for verification because this pollutant is not expected to be related to any manufacturing process. All other organic priority pollutants detected in screening anaylsis for this subcategory were included in verification analysis.

Of the metal priority pollutants, beryllium was reported at its quantifiable limit of detection in all samples, is not known to be used as a raw material and is therefore not selected. Copper is not known to be related to any manufacturing process in this subcategory, was detected at a concentration above its limit of detection in only the influent sample, and is therefore not selected. Although silver was not detected in screening, it is selected as a verification parameter for process wastewaters associated with silver cathode production. All other metal priority pollutants detected in screening analysis for this subcategory were selected for verification. Cyanide was also selected to be analyzed.

A number of nonconventional pollutants were also detected in screening analyses of cadmium subcategory process wastewater. Of these, fluoride, iron, magnesium, manganese, phosphorous, sodium, and tin were detected, but not selected for verification analyses. Ammonia and total phenols were detected in screening and were selected as verification parameters. Cobalt was also selected for verification analysis although it was not detected in screening because it is known to be used as a process raw material at some sites in the subcategory and was expected to occur as a wastewater pollutant at those sites. In addition, the conventional pollutants, TSS, oil and grease, and pH were included for verification analysis.

Calcium Subcategory. Screening results are presented for this subcategory, however, verification parameters have not been selected.

Lead Subcategory. Based on screening analysis and evaluation of this subcategory analysis and evaluation of this subcategory twenty-eight pollutant parameters were selected for further analysis. The twenty-eight are:

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11	1,1,1-trichloroethane	118	cadmium
23	chloroform	119	chromium
44	methylene chloride	120	copper
55	naphthalene	122	lead
65	phenol	123	mercury
66	bis(2-ethylhexyl)phthalate	124	nickel
67	butyl benzyl phthalate	126	silver
68	di-n-butyl phthalate	128	zinc
69	di-n-octyl phthalate		iron
78	anthracene		phenols (4AAP)
81	phenanthrene		strontium
84	pyrene		oil and grease
114	antimony		TSS
115	arsenic		pH

Eighteen organic priority pollutants were detected in screening at concentrations below the quantification level. These pollutants, acenaphthene, benzene, 2,4,6-trichlorophenol, 2-chlorophenol, 1-3 dichlorobenzene, 2,4-dichlorophenol, ethylbenzene, fluoranthene, dichlorobromomethane, chlorodibromomethane, 1,2benzanthracene, 3,4-benzopyrene, 3,4-benzofluoranthene, 11,12-benzofluoranthene, chrysene, fluorene, trichloroethylene, and heptachlor epoxide were neither known to be used in manufacturing within the subcategory nor reported as present in process wastewater by any manufacturer. They were therefore not selected for verification. Five additional organic priority pollutants were reported as believed present in process wastewater by at least one plant in the subcategory but were not detected in screening analysis. On the basis of these negative screening results and the other criteria, 1,2-dichloroethane, dichlorodifluoromethane, PCB-1242, PCB-1254, and PCB-1260, were not selected as verification parameters for the lead subcategory. Toluene was also indicated as believed present in one dcp, and was detected in screening analysis at less than the quantifiable limit. Therefore, it was not selected for verification. Two organic pollutants, methylene chloride, and naphthalene, were included in verification analysis although they were detected only at trace concentrations, because they were reported to be present in process wastewater in dcp's from lead subcategory plants. Pyrene and phenol were selected as verification parameters because they were identified as potential pollutants resulting from oils and bituminous battery case sealants although they also were detected only in trace concentrations. All other organic priority pollutants found to be present in screening analysis for this subcategory were included in verification.

Of the metal priority pollutant parameters beryllium was reported only at the limit of detection, is not known to be related to battery manufacture, and is therefore not selected. Antimony, although reported at the limit of detection was selected because of dcp

responses. All metal pollutant parameters detected in screening above the limits of detection were selected for verification. Arsenic was selected as a verification parameter because it was reported to be present in process wastewater by battery manufacturers and was known to be used in the manufacturing process. Another metal pollutant, mercury, was also selected for verification because it was not analyzed in screening and was reported as believed to be present in process wastewaters by some battery manufacturers. Cyanide was not selected for verification since it was reported in all samples at the limit of detection and was not known to be present in battery process wastewaters.

A number of nonconventional pollutants were also detected in screening, but not included in verification analysis. Iron and total phenols were detected in screening and were consequently included in verification analyses. Iron is present in process wastewater as a result of corrosion of process equipment, and total phenols may derive from oil and grease, and bituminous materials used in manufacturing. Strontium was included in verification analysis although it was not analyzed in screening because it is used as a raw material in manufacturing some batteries in this subcategory. In addition, the conventional pollutants, oil and grease, TSS, and pH were included in verification analysis.

Leclanche Subcategory. Based on screening analysis and evaluation of this subcategory sixteen pollutant parameters were selected for further analysis. The sixteen are:

70	diethyl phthalate	124	nickel
114	antimony	125	selenium
115	arsenic	128	zinc
118	cadmium		manganese
119	chromium		phenols (4AAP)
120	copper		oil and grease
122	lead		TSS
123	mercury		pH

Eleven organic priority pollutants were detected at concentrations less than the quantification levels in screening samples for this subcategory. Eight of these pollutants, 1,1,2,2-tetrachloroethane, dichlorobromomethane, chlorodibromomethane, phenol, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, butyl benzyl phthalate, and dimethyl phthalate, were neither reported to be present in process wastewater by plants in this subcategory nor known to be used in the manufacturing process. The remaining three pollutants, methylene chloride, tetrachloroethylene, and toluene, were reported as known or believed to be present in process wastewater in the priority pollutant section of at least one dcp. Methylene chloride was reported as known to be present and as used in the manufacturing process by one plant.

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This facility also reported, however, that use of this material had been discontinued. Tetrachloroethylene and toluene were reported to be believed to be present in process wastewater by one and two plants, respectively. Their presence cannot be traced to any use in battery manufacturing processes, however, and is believed to derive from on-site plastics processing and vapor degreasing operations which are not regulated as part of the battery manufacturing category. On the basis of these considerations, none of these eleven pollutants were included in verification analyses. Chloroform was detected in screening at concentrations as high as 0.043 mg/l but was not selected for verification because this concentration was in the influent sample. Diethyl phthalate was the only organic priority pollutants detected in screening which was selected for verification analysis.

For metal priority pollutants beryllium and silver were not selected because they were reported at the limits of detection and were not known to be a part of any manufacturing process in this subcategory. Arsenic was selected as a verification parameter although it was not found in screening samples. Arsenic was reported to be believed present in process wastewater by three plants in this subcategory. Further, it is highly toxic and known to be a potential contaminant of zinc which is a major raw material. Selenium was reported to be present in process wastewater by one manufacturer and was reported in screening in the influent sample at the limit of detection. It was therefore included in verification analyses. All other metal priority pollutants were detected in screening and selected for verification.

A number of nonconventional pollutants were detected in screening but not selected as verification parameters. Manganese and total phenols were measured at significant levels in screening and were consequently included in verification analyses. In addition, the conventional pollutants oil and grease, TSS, and pH were selected for verification analysis.

Lithium Subcategory. Screening results are presented for this subcategory, however, verification parameters have not been selected.

Magnesium Subcategory. Screening results are presented for this subcategory, however, verification parameters have not been selected.

Zinc Subcategory. Based on screening analysis and evaluation of this subcategory thirty-three pollutant parameters were selected for further analysis. The thirty-three are:

11	1,1,1-trichloroethane	120	copper
13	1,1-dichloroethane*	121	cyanide
29	1,1-dichloroethylene*	122	lead
30	1,2-trans-dichloroethylene*	123	mercury

38	ethylbenzene*	124	nickel
44	methylene chloride	125	selenium*
55	naphthalene*	126	silver
64	pentachlorophenol*	128	zinc
66	bis(2-ethylhexyl)phthalate*		aluminum
70	diethyl phthalate*		ammonia*
85	tetrachloroethylene*		iron
86	toluene*		manganese
87	trichloroethylene		phenols (total)
114	antimony		oil and grease
115	arsenic		TSS
118	cadmium		pH
119	chromium		

*These parameters were verification parameters for only some battery types within the subcategory.

Screening for this subcategory was performed at two sites producing different battery types, all of which are within the zinc subcategory. Twenty-two organic priority pollutants, ten priority pollutant metals, cyanide, and twenty other pollutants were detected in screening samples from one or both of these facilities. Because screening and verification parameter selection were initially performed on the basis of battery types, two different lists of verification parameters were defined for plants in the zinc subcategory. A number of priority pollutants, mostly organics, were consequently analyzed in only some of the zinc subcategory wastewater samples. These parameters are marked with a * in the listing of verification parameters selected.

Eight of the organic priority pollutants, benzene, 1,1,2-trichloroethane, 2,4,6-trichlorophenol, 2-chlorophenol, butyl benzyl phthalate, di-n-butyl phthalate, anthracene, and phenanthrene, were detected at concentrations below the quantifiable level. None of these pollutants was reported to be present in process wastewater by plants in the subcategory, and none was selected for verification. All other organic priority pollutants observed in screening samples were included in verification analysis.

All of the metal priority pollutants detected in screening were selected for verification with the exception of beryllium which was reported at its quantifiable limit. In addition, arsenic which was not detected in screening analysis was selected as a verification parameter because it is a highly toxic potential contaminant of zinc which was reported to be present in process wastewater by one manufacturer in the subcategory. Cyanide was also detected at less than 0.01 mg/l but was selected as a verification parameter on the basis of its toxicity and potential use in cell cleaning formulations.

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Many nonconventional pollutants were also detected in screening. They were not included in verification analyses. Aluminum, ammonia, iron, manganese, and total phenols were measured at appreciable levels in screening samples and were included in verification analyses. Ammonia, however, was analyzed and selected as a verification parameter based on screening at one plant only and was consequently analyzed in only some verification samples. In addition, the conventional pollutants, oil and grease, TSS and pH were selected as verification parameters.

Summary of Verification Parameters. Table V-8 (Page 262) presents a summary of the verification parameters selected for each subcategory of the battery manufacturing category. Under the discussions and analysis for each subcategory, verification parameter analytical results are discussed and tabulated. *'s in the tables are used for quantifiable limits of the organic pollutants (0.01 mg/l). For chemical analysis, the *'s are calculated as positive values which cannot be quantified, but for statistical analysis are counted as zeroes.

CADMIUM SUBCATEGORY

This subcategory encompasses the manufacture of all batteries employing a cadmium anode. Presently there are ten active plants in the subcategory, nine of which manufacture cells based on the nickel-cadmium electrolytic couple. One of these plants also produces silver-cadmium batteries. The remaining facility manufactures mercury-cadmium cells although production at that facility is reported to be sporadic and quite small in volume. Manufacturing processes in the subcategory vary widely and result in corresponding variations in process water use and wastewater discharge. A total of sixteen distinct manufacturing process operations or functions were identified which are combined in various ways by manufacturers in this subcategory and which provide a rational basis for effluent limitations. After a discussion of manufacturing processes employed in the subcategory and a summary of the available data characterizing cadmium subcategory facilities, each of these sixteen process elements is discussed in detail to establish wastewater sources, flow rates, and chemical characteristics.

Manufacturing Process

As shown in the generalized process flow diagram of Figure V-1, (Page 192), the manufacture of batteries in this subcategory comprises basically the preparation and formation of the anode and cathode, assembly of these components into cells and batteries, and ancillary operations performed in support of these basic manufacturing steps.

Three distinct process elements for the production of anodes, five for the manufacture of cathodes, and eight different ancillary operations are observed in present practice within the subcategory. They are combined in a variety of ways in existing plants to produce batteries exhibiting a range of physical and electrical characteristics. Additional combinations are possible in future manufacturing.

The observed variations in anode and cathode manufacture, and the combinations of these processes at existing plants are shown in Table V-9 (Page 263). This table also presents the ancillary operations which have been observed to involve water use and wastewater discharge and the extent of practice of each of these operations. The x's presented in the table under each anode type and after each cathode type and ancillary operation are identification of reported manufacture of the designated operations. Data from these operations are used in detailed discussions of each of these process elements.

The process operations and functions shown in Table V-9 formed the framework for analysis of wastewater generation and control in this subcategory. Several of them involve two or more distinct process wastewater sources which must be considered in evaluating wastewater characteristics. The relationship between the process elements and discrete waste sources observed at battery manufacturing facilities is illustrated in Figure V-2 (Page 193).

Anode Manufacture - Except for one plant which obtains electrodes produced at another facility, all manufacturers use cadmium or cadmium salts to produce anodes. Three general methods for producing these anodes are currently used which may be differentiated on the basis of the technique used to apply the active cadmium to the supporting structure. In the manufacture of pasted and pressed powder anodes, physical application of solids is employed. Electrodeposited anodes are produced by means of electrochemical deposition of cadmium salts from solution. Impregnated anodes are manufactured by impregnation of cadmium solutions into porous structures and subsequent precipitation of cadmium hydroxide in place.

Cadmium powder anodes encompass anodes in which a cadmium hydroxide mixture is applied to the perforated surface of a supporting grid (usually nickel plated steel) in either a powdered form or compressed powder form. Other anodes included in this grouping are those in which cadmium oxide is blended with appropriate additives prior to either pressing to form a button or pellet or pasting on a supporting grid. The charged state for these anodes is achieved in present practice by formation after cell assembly. The only process wastewater source presently reported from the manufacture of this type of anode is the clean-up of anode production equipment and floor areas.

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One facility reports the manufacture of cadmium hydroxide on-site for use in battery manufacture. Since the grade of cadmium hydroxide produced is unique to battery manufacture, this process is included as an ancillary operation for regulation under this subcategory. Another plant produces cadmium powder which is then blended and used for the manufacture of pasted cadmium anodes. Production of the cadmium powder is considered a separate ancillary operation.

Formation of these anodes outside the battery case, while not presently practiced in the United States, is anticipated in the near future by one manufacturer. This process variation may introduce an additional wastewater source from rinsing the formed anodes prior to battery assembly.

Electrodeposited anodes are produced by electrochemically precipitating cadmium hydroxide from nitrate solution onto the support material. When the appropriate weight of cadmium hydroxide has been deposited, the deposited material is subjected to a charge and discharge cycle while submerged in caustic solution and subsequently rinsed. After drying, the formed material is cut to size for assembly into cells.

The cadmium nitrate solutions used in electrodeposition may be partially supplied by redissolution of excess cadmium hydroxide washed off anodes during processing and recovered from the process rinse water. Dissolution of this material in nitric acid generates acid fumes which must be controlled with a scrubber.

Process wastewater sources involved in the manufacture of electrodeposited anodes include: (1) Rinsing active material deposited on the grid; (2) rinsing electrode material following each phase of formation; (3) spent caustic used in formation; and (4) wet scrubbers.

A third method of cadmium anode manufacture involves submerging porous sintered nickel stock in an aqueous solution of cadmium salts and precipitation of cadmium hydroxide on the sintered material by chemical, electrochemical, or thermal processing. Generally the impregnated material is immersed in a caustic bath to precipitate cadmium as the hydroxide followed by a rinsing stage. The entire impregnation cycle is repeated several times to achieve the desired active material (cadmium) weight gain. After cleaning the anode material by brushing or washing to remove excess deposited material, the anode material is submerged in a caustic solution and an electric current is applied to repeatedly charge and discharge the anode material. Formation is generally followed by rinsing.

Process wastewater from the manufacture of cadmium impregnated anodes results from: (1) cleaning equipment used to prepare porous sintered

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stock; (2) rinsing deposited active material on the sintered support material; (3) removing excess deposited materials prior to formation (which can be preceded by soaking the impregnated stock); (4) rinsing the anode material after formation; and (5) spent caustic used in both the impregnation caustic immersion phase and formation process.

Cathode Production - Three of the five cathode manufacturing process elements involve processes for producing nickel cathodes. The other two processes deal with producing silver cathodes and mercury cathodes.

The production of silver cathodes begins with preparing a silver powder which is sintered. The metallic silver cathode which results is assembled with an unformed cadmium anode. The resulting batteries are shipped in the unformed state. The only source of wastewater discharge associated with this cathode type results from the silver powder production operation which is addressed as a separate ancillary operation. The production of mercury cathodes proceeds by physical compaction of mercuric oxide and generates no process wastewater.

One of the three nickel cathode manufacturing variations (pasted and pressed powder cathodes) includes cathodes produced by physically blending the active materials as solids and molding them into pellets or applying them to supporting grids. This includes cathodes in which nickel hydroxide is blended and subsequently applied to the perforated areas of the grid. In present practice, these cathodes which are produced in the unformed (divalent) state are assembled into batteries with unformed anodes, and the complete battery is subsequently charged.

No wastewater discharge is presently reported from manufacturing cathodes in this group except for effluent from the production of nickel hydroxide by chemical precipitation at one facility. This precipitation process is addressed as a separate ancillary operation in this subcategory.

The other two nickel cathode process variations involve the precipitation of active material from solution onto a conducting support grid. One of these variations is the production of nickel cathodes by electrodeposition. In this process sintered nickel support material is immersed in a nickel nitrate solution and upon applying an electrical current, nickel hydroxide precipitates on the sintered material. The process material is removed from the nitrate solution when the active material weight gain meets specifications. Afterwards the cathode material is subjected to an electrochemical formation process to achieve the charged state of the active material. The two sources of wastewater discharge from the electrodeposition process are from: (1) removing spent caustic used in the formation process; and (2) rinsing the formed cathode material.

The remaining method of nickel cathode manufacture involves the impregnation of sintered stock prepared from powdered nickel with nickel nitrate solution. Afterwards, the process material is removed from the aqueous solution of nickel salts and immersed in caustic solution to precipitate nickel hydroxide in the pores. This is followed by rinsing. The entire impregnation process is repeated several times to achieve the required active material weight gain. After completion of impregnation, excess deposited material is removed by brushing or washing prior to formation.

Formation of impregnated stock is presently accomplished by two different techniques. The most common practice is to sequentially oxidize and reduce the nickel hydroxide by electrolysis in a caustic solution. An alternative technique achieves oxidation and reduction chemically. In either formation technique, post-formation rinses are used to remove impurities liberated from the formed material as well as residual formation solutions. Formation produces changes in the physical structure of active material within the electrode and also serves to remove impurities in addition to changing the electrode's state of charge.

Process wastewater sources observed in the manufacture of impregnated nickel cathodes include: (1) cleaning equipment used to prepare the porous sintered stock which is impregnated; (2) rinsing impregnated stock; (3) washing excess deposited material off impregnated stock (which can be preceded by soaking the impregnated stock); (4) spent formation and impregnation solutions; (5) post-formation rinses; (6) cleaning impregnation equipment; and (7) wet scrubbers.

Nickel hydroxide washed off the impregnated stock in process rinses and in post-impregnation cleaning may be recovered and redissolved in nitric acid to produce some of the nickel nitrate solution used in impregnation. This process may yield additional wastewater streams. These waste streams, where generated, are also considered to be directly attributable to the production of impregnated nickel cathodes.

Assembly - The assembly of cells in this subcategory is accomplished without the generation of process wastewater. Specific assembly techniques differ for different cell types manufactured in this subcategory. For example, anodes and cathodes for large rectangular cells are interleaved with separators which may be plastic or hard rubber rods, while for sealed cylindrical cells, the anodes and cathodes are spirally wound with flexible sheet separators. Assembly of all cells, however, involves the assembly of one or more anodes with cathodes and separators to produce an active cell element. One or more of these elements is then inserted in a battery case, electrical connections made, (as required), and electrolyte added, after which the case is covered and (if appropriate) sealed.

Separators are a key component in these cells, particularly in sintered electrode cells (electrodeposited or impregnated) which are designed to operate at high current drains per unit of electrode surface area. In these cells, minimum separator thickness is desired to minimize internal resistance of the cells and maximize gas diffusion and recombination in sealed cells. The resistance of the separator material to chemical attack and perforation limits the cell performance which can be achieved. Separators in open pressed powder (pocket plate) cells are frequently narrow plastic or hard rubber rods or may be corrugated, perforated plastic sheets. In cells using sintered electrodes, a variety of separator materials are used including woven or non-woven synthetic fabrics, sheet resin, and cellophane. A three layer separator comprising a layer of cellophane between two nylon layers is frequently used. In sealed cells, separators are often made of felted nylon. Separator configurations in use include flat sheets between cathode and anode and a variety of wrapped or folded configurations.

The electrolyte used in these cells is usually potassium hydroxide in solutions ranging between 20 and 30 percent in concentration. Lithium hydroxide is often added to the electrolyte to improve cell performance. Cell cases may be either steel or plastic. Cases or covers used in manufacturing batteries in this subcategory include some provision for venting gases generated in cell charging or on overcharge. Open or vented cells normally generate some hydrogen and have vents which function during normal operation. In sealed cells, design factors minimize gas generation and provide for recombination before pressures rise excessively. Vents in these cells are normally sealed and function only when abnormal conditions cause pressures to rise above normal limits.

Ancillary Operations - A number of process operations or supporting functions in addition to the basic electrode manufacture and assembly steps described above are required for the production of cadmium subcategory batteries. These ancillary operations include: (1) washing assembled cells; (2) preparing electrolyte solutions; (3) cleaning process floor areas; (4) employee hand washing to remove process chemicals; (5) the production of cadmium powder; (6) the production of silver powder; (7) the production of nickel hydroxide; and (8) the production of cadmium hydroxide.

In the course of manufacture and assembly, the cases of batteries are likely to become contaminated with spilled electrolyte and other process materials. Since these contaminants may interfere with electrical contact with the batteries, accelerate contact corrosion, or even damage devices in which the batteries are used, washing some batteries prior to shipment is required. Washing batteries produces a process wastewater stream.

Electrolyte is prepared for use in batteries by solution of potassium hydroxide in the correct volume of water. Process wastewater associated with this operation results from spillage and from washing reagent preparation equipment at some facilities.

Process floor areas typically require periodic cleaning to maintain plant safety and hygiene. This is normally accomplished at least in part by washing, resulting in the production of wastewater contaminated with a variety of process materials. The amount of water reported to be used in and discharged from this operation is highly variable depending on the washing procedures used.

Because nickel and cadmium are both toxic metals, the safety and health of production workers at plants in this subcategory requires that process materials be washed from their hands prior to eating or leaving the work place. Water used in this washing may become contaminated with nickel, cadmium, and other process chemicals and is considered process wastewater.

A special grade of cadmium powder may be produced on-site for use in anode production. The powder is produced by chemical precipitation of cadmium. The precipitated cadmium metal is subsequently washed with water prior to being used in anodes.

Silver powder for use in cathode manufacture is produced on-site at battery manufacturing facilities by electrolytic deposition. This powder, which has physical properties required for batteries, is unique to battery manufacturing. This silver powder is also used in producing cathodes for zinc subcategory cells, and this ancillary operation is therefore discussed and included in the zinc subcategory.

Nickel and cadmium hydroxides for use in the manufacture of pasted or pressed powder electrodes may be produced on-site at battery manufacturing plants. When this occurs, unique grades of these materials containing additives to enhance battery performance are produced.

Nickel hydroxide is produced from nickel powder by dissolution and chemical precipitation. Rinsing the precipitated material generates process wastewater. The nickel hydroxide product contains specific additives to enhance battery performance characteristics.

Cadmium hydroxide is produced at battery plants from cadmium metal by oxidation and hydration. The product contains iron oxide and graphite as well as cadmium hydroxide. Wastewater from this process results only from pump seals and is limited in volume.

Subcategory Data Summary

The manufacture of three battery types, mercury-cadmium, silver-cadmium, and nickel-cadmium batteries, is included in this subcategory. Nickel-cadmium batteries, however, account for over 99 percent of the total mass of cadmium anode batteries produced. Manufacturing plants in the subcategory vary significantly in production volume and in raw materials, production technology, wastewater generation, and in wastewater treatment practices and effluent quality.

Production - Annual production reported in the subcategory totaled 4800 metric tons of batteries in 1976. Using the latest available data (1976-1979), estimated annual production broken down among battery types is shown below:

Battery Type	Estimated Annual metric tons (kkg)	Production tons
nickel-cadmium	5242	5780
silver-cadmium	8.6	9.5
mercury-cadmium	0.045	0.05
Total	5251	5790

Production of nickel-cadmium batteries may be further divided among cells of the pasted or pressed powder varieties and cells containing sintered plates with impregnated or electrodeposited active material. Of the total nickel cadmium batteries reported in 1976, 18 percent or 890 metric tons (980 tons) contained pasted or pressed powder electrodes. The remainder of the nickel cadmium batteries produced contained sintered electrodes. Production ranges from less than 10 to greater than 1000 kkg of batteries annually.

Plants producing batteries in this subcategory are frequently active in other battery manufacturing subcategories as well. Six of the ten present producers of cadmium subcategory batteries also manufacture products in at least one other subcategory at the same location. Other subcategories reported at these sites include the lead, Leclanche lithium, magnesium, and zinc subcategories. Process operations are common to multiple subcategories at only one of these plants, however. Production in other subcategories produces process wastewater at only two other cadmium subcategory plants, and waste streams are combined for treatment and discharge at only one of these. Consequently multi-subcategory production has little if any impact on cadmium subcategory wastewater treatment and effluent quality.

Geographically, plants in the cadmium anode subcategory are dispersed throughout the United States. There are two active facilities in each of EPA Regions I, IV, and V and one each in regions II, VI, VIII, and IX. These plants do not vary greatly in age with the oldest manufacturing facilities reported to be only 15 years old.

Raw Materials - Although there were some variations in raw materials with manufacturing process and product variations, many of the raw materials used in producing cadmium anode batteries were common to all or most facilities. For example, cadmium or its salts are used by all plants, and nickel was reported as a raw material by eleven of thirteen plants supplying data in the subcategory. Of the remaining two facilities, one produced only mercury-cadmium batteries and the other produced nickel-cadmium batteries, but obtained processed electrode material from another site. Cadmium and cadmium oxide are used in the preparation of pasted and pressed powder anodes and may also be used in producing solutions for impregnation and electrodeposition. Cadmium oxide may also be added to nickel cathodes as an antipolar mass in some sealed cells. Cadmium nitrate is used as an aqueous solution in impregnation operations as is nickel nitrate. Nickel hydroxide is used in producing pasted and pressed powder cathodes. Nickel is used in the form of wire as a support and current collector for electrodes and as a powder for the production of sintered stock into which active material may be introduced by impregnation or electrodeposition.

Other raw materials which are frequently reported include nylon, potassium hydroxide, lithium hydroxide, steel, polypropylene, nitric acid, silver nitrate, silver, mercuric oxide, cobalt nitrate and sulfate, sodium hypochlorite, methanol, polyethylene, and neoprene. Nylon is a popular separator material and may also find applications in a variety of cell components such as vent covers. Potassium hydroxide and lithium hydroxide are used as the electrolyte in almost all cells produced in this subcategory although sodium hydroxide is used in electrolytic process operations (e.g. formation) and may be used as the electrolyte in a few cells. Steel is widely used in cell cases and may also be used with a nickel plating as the support grid in some battery types. Polypropylene, polyethylene, and neoprene may all be used in separator manufacture or in cell cases or cell case components. Nitric acid is used in preparing the metal nitrate solutions used in impregnation, and cobalt nitrate or sulfate is introduced into some nickel electrodes to yield desireable voltage characteristics. Silver and silver nitrate are used in producing silver oxide cathodes for silver-cadmium batteries, and mercuric oxide is used in producing cathodes for mercury-cadmium batteries.

Water Use and Wastewater Discharge - Water use and wastewater discharge are observed to vary widely among cadmium subcategory plants

with process wastewater flow rates ranging from 0 to >450,000 l/day. Individual plant effluent flow rates are shown in Table V-10 (Page 264). Most of the observed wastewater flow variation may be understood on the basis of manufacturing process variations. The water use and wastewater discharge from specific process functions varies from zero for the manufacture of pressed powder nickel cathodes to 1640 liters per kg of impregnated nickel (200 gal/lb) for sintered impregnated electrodes. Plants with different process sequences correspondingly produce different volumes of process wastewater. In some cases, however, large differences in process water use and discharge are observed among different plants using the same process operations. As discussed later in this section, on-site observations and data collection at a number of plants in the subcategory revealed differences in plant operating practices which result in the observed flow variations. In general, these differences are observed to result primarily from differing degrees of awareness of water conservation.

Mean and median normalized discharge flows from both dcp and visit data for each of the wastewater producing process elements included in this subcategory are shown in Table V-11 (Page 265). This table also presents the production normalizing parameters upon which the reported flows are based which were discussed in Section IV.

Wastewater Treatment Practices and Effluent Quality - Among plants in this subcategory which presently report wastewater discharges, all but one reported treatment of wastewater for removal of suspended solids by settling or filtration. Four out of seven facilities also report pH adjustment of the waste prior to discharge. On-site observations, however, showed that the quality of treatment provided was variable and that some systems were of marginal design with limited retention times in setttling devices and little or no control over surge flows. The effects of these conditions are evident in the effluent monitoring data provided in dcp's as summarized in Table V-12 (Page 266). One plant employs ion exchange to recover nickel and cobalt from process wastewater prior to discharge. Other waste streams at this site are treated by pH adjustment, sedimentation and filtration.

Specific Process Water Uses and Wastewater Characteristics

Anode Operations

Cadmium Pasted and Pressed Powder Anodes - Preparation of these anodes involves blending solid constituents and physically applying them to support structures. In some cases a limited quantity of water may be added to the solid constituents to form a paste prior to application. Preparation of the solid active materials is not included in this process group although it is performed on-site at a few facilities. Specific materials and techniques differ somewhat among plants and product types.

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In the manufacture of pocket plate anodes, the current collector-support structure is a perforated metal sheet upon which a mixture of cadmium oxide, hydroxide, and binders is pressed. Alternatively, the active material may be pressed into pellets prior to application to the electrode support. Two facilities report the preparation of anodes by the application of a paste containing powdered cadmium as well as cadmium oxides and hydroxides to a supporting grid. In the manufacture of nickel-cadmium batteries, the supporting grid is usually nickel-plated steel. The use of a silver grid and a blended powder containing silver as well as cadmium oxide is reported in the production of anodes for silver-cadmium batteries. Six plants reported production of pasted or pressed powder cadmium anodes. Two of these facilities were visited for wastewater sampling and on-site data collection. One additional plant presently produces active material for use in pocket plate anodes and assembles batteries. One plant has discontinued production in the cadmium subcategory since submission of the dcp.

Limited use and discharge of process water is inherent in the production process involved in producing these anode types. The only wastewater discharge from anode production in this group is process area maintenance. Two plants (A and B) use water to clean floors and equipment. The resultant wastewater was sampled at plant A. The analysis results are presented in Table V-13 (Page 267). The normalized flow from this source ranges from 1.5 to 2.7 l/kg of cadmium applied in anode manufacture (1.9 l/kg mean and 1.8 l/kg median). Cadmium, nickel, TSS, and oil and grease are the significant pollutants found in this waste stream. Cadmium, nickel, and TSS apparently result from spillage of process chemicals which are handled in bulk in the anode preparation area. The equipment used in handling both the bulk chemicals and processed materials is also washed contributing to the oil and grease wastewater levels. Table V-14 (Page 268) shows the pollutant mass loadings in the clean-up waste stream on three successive days.

Formation of anodes in this group does not presently produce a process wastewater discharge at any plant in the U.S. Two plants did not report a formation step in the production of pasted cadmium anodes. One plant assembles cadmium oxide pressed powder anodes with silver pressed powder cathodes, and the product is shipped to the customer. Formation is conducted within the battery case prior to use. Other facilities report formation of these anodes in assembled batteries without the generation of process wastewater.

Cadmium Electrodeposited Anode – The electrodeposition process involves the precipitation of cadmium hydroxide from nitrate solution onto a support material by application of an electric current. It is followed by an electrolytic discharging charging cycle called

formation. Rinsing follows both electrodeposition and formation processes. Figure V-3 (Page 195) is a flow diagram for the production of anodes by the cadmium electrodeposition process.

The wastewater resulting from cadmium electrodeposition was sampled at one facility allowing pollutant characterization and confirmation of the information provided in dcp's. Three sources of wastewater discharge are associated with cadmium electrodeposition: (1) electrodeposition rinses, (2) scrubber bleed-off, and (3) caustic removal. The first two wastewater discharges cited above were sampled separately, and wastewater flow rates were measured for each source. Formation caustic was contractor removed and was not characterized by sampling.

Characteristics of the total electrodeposition process wastewater discharge were determined by combining analysis results of the waste streams discussed above. Tables V-15 and V-16 (Pages 269 and 270) show the pollutant concentrations and mass loadings in units of mg/l and mg/kg, respectively, for the entire process sequence on a daily basis.

Cadmium Impregnated Anode - The impregnation process involves submerging porous sintered material in an aqueous solution of cadmium salts and the subsequent precipitation of cadmium hydroxide on the sintered material by immersion in a caustic bath. The impregnated stock is later rinsed to remove residual caustic. The impregnation cycle is repeated several times to achieve the appropriate weight gain of active material. After completing impregnation, excess material is brushed or scrubbed off the grid surface, and the remaining processed material is ready for formation. The final preparation of the anode material is conducted during electrochemical formation in which cadmium is reduced to the charged (metallic) state, residual nitrates are eliminated, and any remaining poorly-adherent particles are removed from the anode material. A rinse follows the formation process to clean the anode material of residual formation caustic. Figure V-4 (Page 196) is a flow diagram of the entire process sequence for production of impregnated anodes.

Five plants in the data collection survey reported using the cadmium impregnation process. One plant has subsequently discontinued cadmium anode manufacture. Wastewater resulting from the manufacture of impregnated cadmium anodes was characterized by sampling at one facility. Raw materials used in the manufacture of impregnated cadmium anodes include cadmium nitrate, sodium hydroxide, potassium hydroxide, nickel powder, alcohol, and nickel-plated steel.

The manufacture of these anodes generally starts with the preparation of sintered nickel stock. This is accomplished by applying nickel powder, either dry or as a paste containing alcohol and binders, to a

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nickel or nickel plated steel screen and sintering the product in a furnace. Small quantities of wastewater may result from washing utensils used in preparing and applying the nickel paste or powder. The sintered stock is then placed in tanks for impregnation. An electric potential may be applied to the sintered stock during impregnation to enhance cadmium deposition and reduce residual nitrate levels. The entire impregnation cycle is repeated several times before the anode material is taken out of the tank. At some plants it may then be soaked in water to prevent drying of the active material. The anode stock remains soaking until cleaned to remove excess cadmium hydroxide from the grid surface. Afterwards the material may be returned to soak until formation. In formation the anode material is submerged in potassium hydroxide and undergoes electrochemical charge-discharge cycles. At the conclusion of this process, the charged material is rinsed in softened water and later air dried and cut to an appropriate size for battery assembly.

There are seven points of discharge in this process sequence including (1) sintered stock preparation clean-up; (2) cadmium impregnation rinses; (3) impregnation caustic removal; (4) electrode cleaning water discharge; (5) soak water discharge; (6) formation caustic removal; and (7) post-formation rinse.

Two sample days' analysis results are presented to characterize the raw waste from the cadmium impregnation process. The first day's sampling results are excluded from use in the characterization since the impregnation process did not operate on that day. All waste streams were sampled except sintered stock preparation cleanup and the formation caustic dump on the third day. The spent formation caustic waste stream is not included in the combined stream analysis for that day; however, the spent caustic would not contribute significantly to the pollutant concentrations since the flow is 0.5 percent of the total flow. Wastes from anode cleaning, which are included in the analyses shown, are not observed at all sites producing impregnated cadmium anodes. Table V-27 (Page 281) shows the raw waste composition of the combined streams in units of mg/l on a daily basis. The daily pollutant mass loadings in units of milligrams per kilogram of applied cadmium are also presented in Table V-17. In evaluating these data, it should be noted that the wastewater characteristics for the impregnation rinse on day 3 are not considered representative of the normal process discharge. The data for day 2 are considered to provide the best available characterization of the total raw waste from this process operation.

Cathode Operations

Silver Powder Pressed Cathode - This process operation addresses the production of cathodes by the application of silver to conductive supporting grids. The cathode material in the silver state is

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assembled with cadmium oxide anode material, and the final product is shipped unformed to the customer. The battery is charged prior to use.

No process wastewater is generated in this process. Wastewater does result from the production of silver powder for use in these electrodes. This discharge source is addressed as a separate ancillary operation which is common to both the cadmium and zinc subcategories.

Mercuric Oxide Cathodes - The manufacture of mercuric oxide cathodes for use in cadmium subcategory batteries proceeds by physical compaction of the powdered material. No process wastewater discharge from this operation is reported.

Nickel Pressed Powder Cathodes - The manufacture of pressed powder cathodes including cathodes commonly described as "pocket plates" in the literature is accomplished by blending solid powdered material and physically applying the resultant mixture to a conductive supporting grid. Subsequently, the electrode may be formed by cycling it through several charge-discharge sequences to develop maximum electrical capacity. The materials blended for application to pocket plate grids generally include nickel hydroxide which is the primary active material in the cathode, cobalt hydroxide added to modify the battery's voltage characteristics and increase electrical capacity, graphite which provides conductivity from the grid through the bulk of the active material, and binders added to provide mechanical strength.

One plant presently produces nickel cathodes in a process similar to that described above. Electrode formation prior to assembly into batteries is not reported by that facility, and no battery manufacturing process wastewater is produced. One other plant presently produces active material for use in pressed powder cathode manufacture and assembles batteries.

No present manufacturer of these electrode types produces process wastewater in their manufacture.

Nickel Electrodeposited Cathode - The electrodeposition process involves nickel hydroxide precipitation from nitrate solution by electrolysis with a subsequent discharging charging cycle in caustic solution. After electrochemical formation is completed, the cathode material is rinsed to remove residual caustic. Figure V-5 (Page 197) is a schematic diagram of the nickel electrodeposition process.

Sintered nickel grids prepared by either the slurry or dry methods are used as the substrate upon which nickel hydroxide is electrodeposited. Nickel powder in either a slurry or dry form is layered on nickel-plated steel which passes through a furnace for sintering. No water

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is discharged from the sintering operation. Afterwards, the sintered material is positioned in the electrodeposition tank and the tank is filled with a nitric acid solution of dissolved nickel and cobalt salts. An electrical current is applied to the tank causing nickel and cobalt hydroxides to precipitate on the sintered material. The presence of cobalt in the nickel active material aids in the charge efficiency. After deposition of the desired amount of nickel hydroxide, the material is submerged in potassium hydroxide for electrochemical formation. After formation is completed, the cathodes are removed from the tank for subsequent rinsing and the spent formation caustic is dumped. Waste streams resulting from this process are: (1) spent formation caustic removal; and (2) post-formation rinse discharge. Wastewater from this operation was characterized by sampling. Table V-18 (Page 272) presents the verification analysis results of the post-formation rinse discharge (on a daily basis). Table V-19 (Page 273) presents the daily pollutant mass loadings based on the weight of active nickel applied to produce the cathode.

Nickel Impregnated Cathode - The impregnation process involves submerging porous sintered stock in an aqueous solution of nickel salts. Afterwards the product is immersed in a caustic solution to precipitate the nickel as nickel hydroxide. The material is subsequently rinsed to remove caustic, excess nitrate, and poorly adherent particles. The entire impregnation cycle is repeated several times until the appropriate weight gain of active materials is achieved. During impregnation and precipitation, an electric potential may be applied to the sintered stock to enhance nickel deposition and reduce residual nitrate levels in the impregnated product. In addition to nickel nitrate, impregnation solutions may contain cobalt nitrate to modify electrode voltage characteristics and increase electrical capacity. In some cases, impregnation with nickel salt is accompanied by impregnation with a smaller quantity of cadmium nitrate to introduce an anti-polar mass (see Section III) into electrodes intended for use in sealed cells.

After impregnation has been completed, the cathode material is cleaned to remove excess deposited material. The electrodes are then either formed or assembled into cells for subsequent formation in the battery case. Electrodes formed prior to assembly are typically subjected to several charge-discharge cycles to develop the desired physical structure and electrical characteristics and to remove impurities. These electrodes are customarily rinsed after the formation process resulting in a process wastewater discharge. Formation may be accomplished either by application of electric current to the electrodes in a caustic solution or by chemical oxidation and reduction.

Preparation of the sintered stock required for impregnation using nickel powder is also considered part of this process function. This

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operation may result in a process wastewater discharge from the clean-up of tools used to prepare and apply nickel powder paste to supporting grids prior to sintering.

Figure V-6 (Page 198) is a flow diagram of the process for producing impregnated nickel cathodes. As shown in the figure, a total of eleven different sources of process wastewater are associated with this process. These wastewater sources include: (1) nickel paste clean-up; (2) spent impregnation caustic; (3) impregnation rinses; (4) impregnation scubbers (used for nitric acid fume control); (5) impregnated stock brushing; (6) pre-formation soak water, (7) spent formation caustic; (8) post-formation rinses; (9) impregnation equipment wash; (10) nickel recovery filter wash; and (11) nickel recovery scrubber.

Seven facilities reported the manufacture of impregnated nickel cathodes. One of these has subsequently moved their production. Of the remaining six facilities, four plants, A, B, C, and D, were visited for on-site data collection and wastewater sampling. These facilities represented a variety of process options and collectively produced all of the wastewater streams identified. Total wastewater discharges from nickel cathode production were characterized for each day of sampling at each facility by summing the discrete waste streams characterized above. This approach was required because waste streams from individual process steps are frequently treated separately (and directed to different destinations) or combined with wastewater from other process functions. As a result, a single total process raw wastewater stream was not generally available for sampling. The calculated total wastewater characteristics for the production of impregnated nickel cathodes are presented in Table V-20 (Page 274). Table V-21 (Page 275) presents corresponding pollutant mass loadings. Statistical analyses of these data are presented in Tables V-22 and V-23 (Pages 276 and 277).

Ancillary Operations

Cell Wash - This process operation addresses washing either assembled cells or batteries following electrolyte addition. The caustic electrolyte consisting primarily of potassium hydroxide may be spilled on the cell case during filling. The cells are washed to remove the excess electrolyte and other contaminants.

Three plants (A, B, and C) in the subcategory reported cell wash operations. Other facilities produce comparable products without the need for cell washing. The quantity of water used to wash cells ranges from 3,032.0 to 15,745.6 liters per day (7520.8 l/day mean and 3784.8 l/day median). The normalized discharge flows based on the weight of finished cells range from 1.24 to 10.3 liters per kilogram (4.93 l/kg mean and 3.34 l/kg median). The discharge flow rate

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reported by plant B, however, reflects the combined wastewater from cell washing and floor area clean-up.

The cell wash wastewater at these facilities was not sampled and no historical sampling data specifically representing wastewater from the wash operations was provided. However, no materials were reported to be used in the cell wash operation and the electrolyte addition to the cells prior to washing is not expected to contribute pollutants to the waste stream which are not present in process wastewater streams previously sampled.

Characteristics of cell wash wastewater streams resulting from the manufacture of alkaline electrolyte batteries are expected to vary little among different battery types. Sampling data from cell wash operations in the zinc subcategory, Tables V-100 and V-101 (Pages 360 and 361), are considered indicative of cadmium subcategory cell wash effluent characteristics. Cadmium subcategory cell wash discharges, however, are expected to contain nickel and cadmium rather than mercury, manganese, and zinc.

Electrolyte Preparation - Electrolyte addition to assembled cells involves pumps and other equipment which are intermittently cleaned. Two plants reported wastewater discharge from electrolyte preparation. The flows based on weight of finished cells are 0.13 and 0.02 l/kg, respectively. The clean-up wastewater was not sampled, and no historical sampling data was provided specifically representing the waste stream. The only raw materials involved are potassium hydroxide and lithium hydroxide which are not expected to contribute any priority pollutants to the waste stream. The volume and pollutant loads contributed by this wastewater source are minimal.

Floor Wash - Some facilities use water for floor maintenance in process and assembly areas. Three plants in the data base reported using water to clean floor areas. The discharge flow from this source ranges from 0.25 to 33.4 liters per kilogram of finished cells.

The floor wash water for maintaining both impregnation and electrode-position process areas as well as the assembly area was sampled at one plant. The analysis results in units of mg/l are presented in Table V-24 (Page 278). In addition, Table V-25 shows the pollutant mass loadings in units of mg/kg of cells produced. Pollutants in the floor wash discharge include nickel, cobalt, cadmium, and zinc. Both nickel and cobalt are present due to cleaning the nickel cathode process floor areas. Floor maintenance in the vicinity of the cadmium anode production is the primary contributor of cadmium in the wastewater. The source of zinc is not readily determined.

Employee Wash - For purposes of health and safety, some plants require employees to wash hands prior to lunch and at the end of the work

shift to remove process chemicals. Hand-wash water was sampled at one plant. These samples primarily reflect wash water that was used to clean the hands of employees assembling nickel-cadmium batteries as opposed to wash water used by process operators who handle the active material. The analysis results presented in Table V-26 show that the wastewater contains primarily oil and grease and TSS which are present due to the nature of the assembly operations. On the first sampling day, all pollutant levels are low since the sample was taken during the second shift when there were only a few employees assemblng batteries. The other two samples were taken during the first shift when approximately fifteen times the employees washed their hands. Table V-27 (Page 281) presents the pollutant mass loadings based on weight of finished cells produced for each sample day.

Cadmium Powder Production - Cadmium powder production involves chemical precipitation of cadmium. The cadmium may be returned to the initial mixing step when the powder does not meet specifications.

Wastewater discharge from cadmium powder production results from product rinsing and from air scrubbers used to control fumes from process solutions. Wastewater from product rinsing was characterized by sampling. The resulting concentrations together with corresponding pollutant mass loadings based on the total discharge flow are shown in Table V-28 (Page 282).

Silver Powder Production - The production of silver powder used specifically for battery cathodes is produced primarily for silver oxide-zinc batteries, and also for silver-cadmium batteries. Discussion of this operation is under ancillary operations in the zinc subcategory, on page 191. Analysis results from wastewater samples collected on three successive days are presented in Table V-118 (Page 378). Production normalized discharge volumes and corresponding pollutant mass loading for each sampling day are shown in Table V-119 (Page 379).

Nickel Hydroxide Production - Nickel hydroxide for use in battery manufacture is produced by preparation of a solution containing nickel and cobalt sulfates, precipitation of hydroxides from the solution, and washing and drying the precipitate. In addition, graphite may be added to the precipitated hydroxides. Wastewater discharge from this process results from washing the precipitate. The reported discharge volume from this source is 110 l/kg.

This operation was observed during data collection for this study, but the resultant wastewater discharge was not characterized by sampling. At that facility the wastewater from product washing is treated by ion exchange to recover nickel prior to discharge. Characteristics of the resultant effluent as supplied by the plant are presented in Table V-12 (Page 266).

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Cadmium Hydroxide Production - Cadmium hydroxide for battery manufacture is produced by thermal oxidation, addition of nickel sulfate, hydration, and drying of the product. Process wastewater results only from contamination of seal cooling water on slurry pumps used in hydration. The total volume of this waste amounts to 0.9 l/kg based on the weight of cadmium contained in the cadmium hydroxide produced.

As discussed for nickel hydroxide production, this operation was observed but its effluent was not characterized by sampling. Wastewater from cadmium hydroxide production is combined with other process waste streams prior to treatment by chemical precipitation and clarification (by sedimentation and polishing filtration). Reported characteristics of the resultant discharge are presented in Table V-12 (Page 266).

Total Process Wastewater Discharge Characteristics

Total process wastewater characteristics were determined by sampling at four plants in the cadmium subcategory. These characteristics, reflecting the combined raw waste streams from all cadmium subcategory process operations at each site on each of three days of sampling, are summarized statistically in Table V-29 (Page 283). Prevailing discharge and treatment patterns in this subcategory generally preclude directly sampling a total raw waste stream because wastes from individual process operations are often treated or discharged separately. In other cases, individual process wastes are mixed with other waste streams such as non-contact cooling wastes and electroplating wastewater prior to combination with other cadmium subcategory waste streams. Consequently, the total process wastewater characteristics shown in Table V-29 were determined for each plant by mass balance calculations from analyses of wastewater samples from individual process operations.

As Table V-29 shows, concentrations of some pollutants were observed to vary over a wide range. These variations may generally be related to variations in manufacturing processes discussed in the preceding pages. Despite the observed variations, it may be seen that the most significant pollutants are generally consistent from plant to plant and that waste treatment requirements of all of the sampled plants are quite similar.

CALCIUM SUBCATEGORY

Introduction

This subcategory encompasses the manufacture of thermal batteries for military applications. These batteries are designed for long term inactive storage followed by rapid activation and delivery of

relatively high currents for short periods of time. This is accomplished by the use of solid electrolytes which are heated to above their melting point to activate the cell. Heat is supplied by chemical reactants incorporated in the cell distinct from the anode and depolarizer. Because calcium, the cell anode material, reacts vigorously with water, water use and discharge in manufacturing these batteries is quite limited. Production volumes are generally small and manufacturing specifications vary depending upon military specifications for particular batteries. The most significant pollutants found in the limited volumes of wastewater generated in this subcategory are asbestos and chromium.

Manufacturing Processes

In general, the manufacture of calcium anode thermal batteries involves the preparation of the cell anode, depolarizer, electrolyte, and the cell activator (heating element). This is followed by mechanical assembly of these elements together with current collectors, insulators, initiators, and containers to produce cells and multicell batteries. Process water using steps are limited to heating component production and, in some cases, testing and plating of the completed battery assembly. Water may also be used and waste-water generated in the disposal of calcium scrap. A generalized process flow diagram is shown in Figure V-7 (Page 199). The relationship between the process elements and discrete wastewater sources reported at battery facilities is illustrated in Figure V-8 (Page 200).

Calcium anode material is generally produced by vapor deposition on a metallic substrate such as nickel or iron which serves both as a current collector and support for the calcium durin⌐ ⌐e⌐⌐ operation. Because of the high reactivity of metallic calcium with water, this process and all subsequent assembly operations involving the anode are accomplished without the use of water and, in fact, must be performed in areas of reduced humidity.

Depolarizers for these cells include calcium chromate, tungstic oxide, and potassium dichromate. They may be prepared for use in the cells in a variety of ways including impregnation of fibrous media, pelletization of powders, and glazing. All are accomplished without the use of process water. Electrolyte processing is similar and some cell designs in fact combine the depolarizer and electrolyte. Essentially all cells presently produced employ a lithium chloride-potassium chloride eutectic mixture as the depolarizer.

Impregnation of fibrous media such as glass tape is accomplished by dipping the fibrous material in a fused bath of electrolyte, depolarizer, or mixture of electrolyte and depolarizer. The impregnated material is subsequently allowed to cool and cut to shape

for the specific cell design being constructed. Alternatively, the depolarizer or electrolyte may be ground to powder, mixed with a binder such as kaolin or silica, and pressed to form a pellet of suitable size and shape. In general, pellets containing the depolarizer contain electrolyte as well to ensure adequate conductivity, and multi-layer pellets containing both depolarizer and electrolyte layers are produced. Pellets are also produced which contain a homogeneous mixture of electrolyte and depolarizer throughout.

The heating component containing highly reactive materials is an essential part of a thermal cell. Two basic types of heating components are reported in present use, heat paper containing zirconium powder and barium chromate, and heat pellet containing iron powder and potassium perchlorate. Heat paper is produced in a process which involves process water use and wastewater discharge. Initially zirconium powder, barium chromate (which is only sparingly soluble), and asbestos fiber are mixed as an aqueous slurry. The slurry is then filtered to produce a damp paper containing the zirconium and barium chromate as well as the asbestos fiber. The filtrate is generally treated by settling and discharged. Heat pellets are prepared by mixing potassium perchlorate and iron powders and pressing the mixture to form a pellet. This process involves no water use or discharge. Heat paper is non-conductive during cell operation and must be used in cells designed to accommodate this insulating layer. Heat pellets become conductive during operation and may be used as the cathode current collector as well as the source of heat to activate the cell.

Assembly of batteries from these components frequently involves the creation of stacked multi-cell structures to provide voltages considerably above the single cell output (generally 2.5-3 volts). Assembly is under rigid quality control specifications and is accomplished primarily by hand with frequent intermediate tests and inspections. No water is used.

After assembly has been completed, and the cells are hermetically sealed, they may be immersed in a water bath to test for leakage. The contents of this bath may be discharged on an infrequent basis. It is also common to tin or cadmium plate the case of assembled thermal batteries. Wastewater discharges resulting from these operations are not regulated under effluent guidelines for the battery manufacturing category.

Subcategory Data Summary

Calcium anode batteries are produced at three plants. All production is of specialty products governed by military specifications, and products at different plants are not, in general, interchangeable.

Raw materials used in manufacturing these batteries include: calcium, iron, lithium chloride, potassium chloride, calcium chromate, silica, kaolin, asbestos, zirconium, barium chromate, glass fiber, and potassium dichromate. Specific materials vary somewhat from site to site although the use of calcium, iron, lithium and potassium chloride, calcium chromate, zirconium, barium chromate, and asbestos is common to all manufacturers of these batteries. Present trends are to eliminate the use of calcium chromate and barium chromate in new designs by substituting alternative depolarizers and heat sources. Military specifications for existing designs, however, make it unlikely that use of these materials in manufacturing will be discontinued altogether. Because of the limited use of water in manufacturing batteries in this subcategory, only zirconium, asbestos, barium chromate, calcium, and iron are likely to contact process water or enter process wastewater at these facilities. Other process raw materials may enter area wash water during infrequent shut down and maintenance periods, but since normal clean-up is dry, the total volume of water used in clean-up and the amount of these materials discharged are very small.

Wastewater flows in this subcategory result only from the production of heat paper as discussed above. The highest volume reported by any plant in the subcategory is 60.7 l/hr (16 gal/hr). When normalized on the basis of the weight of reactants used (barium chromate and zirconium), the highest wastewater flow is 24.1 l/kg (2.9 gal/lb). Present treatment practice is limited to settling and process wastewater is either contract removed or discharged to a POTW. One plant presently reports no process wastewater from the manufacture of calcium subcategory batteries.

Effluent characteristics reported by one plant in this subcategory are presented in Table V-30 (Page 284). Data reported by this plant are specifically for the effluent from heat paper production.

LEAD SUBCATEGORY

Batteries manufactured in this subcategory employ lead anodes, lead peroxide cathodes, and acid electrolytes. Lead subcategory products, however, vary significantly in physical configuration, size, and performance characteristics. They include small cells with immobilized electrolyte for use in portable devices, batteries for automotive starting, lighting, and ignition (SLI) applications, a variety of batteries designed for industrial applications, and special reserve batteries for military use. Lead reserve batteries are produced from lead electroplated on steel and an acid electrolyte. Process wastewater is generated only from the electroplating operations which are not considered under battery manufacturing. The SLI and industrial batteries are manufactured and shipped as "dry-charged" and "wet-charged" units. Dry-charged batteries are shipped

without acid electrolyte and may be either "damp" or "dehydrated" plate" batteries as described in Section III. Wet-charged batteries are shipped with acid electrolyte. Significant differences in manufacturing processes correspond to these product variations.

Process water use and wastewater discharge varies widely among lead subcategory plants reflecting differences in water use control and wastewater management practices as well as manufacturing process variations. The manufacturing process variations which most significantly influence wastewater discharge are in electrode formation techniques, but these variations are frequently overshadowed by variations in plant water management practices. Wastewater treatment practices are also observed to vary widely resulting in significant variability in effluent quality. Most plants in the subcategory presently discharge process wastewater to POTW, and many provide little or no pretreatment.

Manufacturing Process

The manufacture of lead batteries is illustrated in the generalized process flow diagram presented in Figure V-9 (Page 201). As shown in the figure, processes presently used in commercial manufacture generally involve the following steps: (1) Grid or plate support structure manufacture; (2) leady oxide manufacture; (3) pasting processes designed to provide a plate with a highly porous surface; (4) curing to ensure adequate paste strength and adhesion to the plate; (5) assembly of plates into groups or elements (semi-assembly); (6) electrolyte addition as appropriate; (7) charging or formation which further binds the paste to the grid and renders the plate electrochemically active; (8) final assembly; (9) testing; (10) washing; and (11) final shipment. Each of these process steps may be accomplished in a variety of ways. They may also be combined in different overall process sequences depending on use and desired characteristics of the batteries being produced. These process steps, and their various implementations form the basis for analysis of lead subcategory process wastewater generation and control as shown in Figure V-10 (Page 202).

Grid Manufacture - A lead or lead-alloy grid is the mechanical framework to support active material (lead or lead peroxide) for a battery plate or electrode. Cast or perforated grids are designed to provide mechanical strength, paste adhesion, and electrical conductivity while minimizing the grid weight in relation to the weight of active material in the paste. Alloys reported in dcp's include lead-antimony, and lead-calcium, sometimes with the addition of tin. The literature also indicates that lead-strontium grids may be used and that trace amounts of arsenic, cadmium, selenium and silver may be added to grids. Newly developed grid structures discussed in the literature use ABS plastic grids coated with lead or

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polystyrene interwoven with lead strands for the negative plate, but no plant reported commercial manufacture of these grid types.

Pure lead grids are used in the manufacture of batteries designed especially for applications requiring low self-discharge rates. Their use is limited in most batteries by the relatively low strength provided by pure lead per unit of grid weight.

Lead-antimony has long been considered a most desirable alloy for grid manufacture because of its ability to form easily molded castings capable of sustained strength under charging cycle conditions while providing a low expansion coefficient relative to lead. Antimony retards positive grid growth and corrosion. It migrates from the positive grid into the positive (lead peroxide) paste increasing paste adhesion during cycling to prolong plate life. Unfortunately, when antimony leaves the grid, it can also enter the electrolyte to plate out onto the negative plate (lead) increasing self discharge during open circuit stand and liberating hydrogen in preference to the reduction of lead sulfate (local action) during charging. This effect is diminished by the addition of trace amounts of selenium.

The use of lead-calcium alloy grids has allowed the development of sealed maintenance-free batteries. Increased production of calcium alloy grid batteries has resulted from improvements in techniques for casting calcium-lead grids. Batteries with calcium-alloy grids were originally developed by the telephone companies for float service where the battery is maintained in a charged condition to automatically take care of power required by a fluctuating load. Current required for this application is 1/5 to 1/8th that needed by batteries with lead-antimony grids. For these stationary applications, calcium alloy grids compete with pure lead grids. Recently, sealed batteries using calcium alloy grids have become increasingly popular for automotive use. Lead-strontium alloys may be used for similar reasons and are easier to cast. Calcium alloy grids are also manufactured by punching or perforating, by the expanded metal process, and by wire forming techniques.

Among other additives to lead alloys, arsenic and silver inhibit grid growth on overcharge and reduce postive grid corrosion, tellurium provides finer grain and corrosion resistance, tin produces well defined castings, and cadmium improves mechanical properties of the lead. Impurities common to grid lead include copper, cuprosilver, zinc, bismuth, and iron. Water discharge from this step is not included in the battery manufacturing category but process wastewater is rarely produced as a result of grid casting operations.

Active Material, Oxide Manufacture - Active materials for the positive (PbO_2) and negative (Pb) plates are derived from lead oxides in combination with finely divided lead. Lead oxide (PbO) used in

battery plates and known as litharge exists in two crystalline forms, the yellow orthorhombic form (yellow lead) and the red tetrogonal form. Red lead (Pb_3O_4) is sometimes used in making positive plates, but its use is declining. The lead oxide mixture (PbO and Pb) called leady oxide, which is most often used in producing electrodes, is usually produced on-site at battery manufacturing plants by either the ball mill process or the Barton process. Leady oxide generally contains 25-30 percent free lead with a typical value observed to be approximately 27 percent.

In the ball mill process, high purity lead pigs or balls tumble in a ball mill while being subjected to a regulated flow of air. Heat generated by friction and exothermic oxidation causes oxidation of the eroding lead surface to form particles of red litharge and unoxidized metallic lead. The rate of oxidation is controlled by regulation of the oxidizing air flow and by non-contact cooling of the ball mill.

In the Barton process, molten lead is fed into a pot and vigorously agitated to break lead into fine droplets by aspiration. Oxidation in the presence of an air stream forms a mixture of yellow lead, red litharge, and unoxidized lead in a settling chamber.

High purity refined lead is required to produce oxide for electrodes used. Recycled lead recovered by remelting scrap is normally used in casting grids, straps, and terminals.

Wastewater from lead oxide production (except for leady oxide) is not included for regulation under the battery manufacturing category. While the production of leady oxide is included in the battery manufacturing category, only non-contact cooling water is used at most sites, although some plants reported having contact wastewater and scrubber discharge wastewater.

Pasting Processes - The process of pasting lead oxides on the grid produces electrode plates with a porous, high area, reactive surface. The pores allow maximum contact of ions present in the electrolyte with the electrode. Various mixtures of lead oxide powder are used for the formulation of the negative and positive pastes, which usually are mixed separately. The positive plate is formed from leady oxide, granular lead, in some cases red lead, binders such as acrylic fibers, sulfuric acid, and water. The negative paste generally contains leady oxide, lead, sulfuric acid, water, and expanders. Expanders are added to the negative paste to minimize contraction and solidification of the spongy lead. The most common expanders are lampblack, barium sulfate, and organic materials such as ligninsulfonic acid. Addition of expanders amounting to an aggregate 1 or 2 percent of the paste can increase negative plate effective area by several hundred percent.

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While hardeners have been added to pastes (e.g. glycerine and carboxylic acid), prevailing present practice is to control these properties by proper oxide processing. Other additives to the paste include ' ammonium hydroxide, magnesium sulfate, lead carbonate, lead chloride, lead sulfate, potash, and zinc chloride. Where a plate is to be placed in a dehydrated battery, mineral oil may be added to the negative paste to protect the plate from oxidation, from sulfation, and to reduce hydrogen evolution (depending upon the grid alloy).

Water added to the paste functions to produce proper consistency and increase paste adhesion. During acid addition, considerable heat is evolved requiring temperature control to provide a paste with the proper cementing action.

Paste is applied to the grids by hand or machine. Water is required to clean the equipment and the area. This water is usually recycled after settling to remove particulates. It contains large concentrations of lead as well as the various additives used in the paste and, where discharged to treatment, greatly increases raw waste pollutant loads. Process wastewater may also be generated by wet scrubbers in the pasting areas.

<u>Drying</u> <u>and</u> <u>Curing</u> - The drying and curing operations are very important in providing electrodes with the porosity and mechanical strength required for adequate battery performance and service life. The purpose of this step is to ensure proper control of oxidation and sulfation of the plates.

Where leady oxides are present, common practice is to flash dry the plates by passing them through a tunnel drier and then either stacking and covering or placing in humidity controlled rooms for several days to convert free lead particles in the plates to lead oxide. In this process the free lead is reduced from 24-30 percent to the desired level (5 percent or less). Proper conditions of temperature and humidity cause the formation of small crystals of tribasic lead sulfate which convert easily to a very active lead peroxide (positive plate) during formation. Too high a temperature (57°C) leads to the formation of coarse crystals of tetrabasic lead which is difficult to convert to lead peroxide and may cause shedding of active material during formation. Too little or too much moisture in the plate retards the rate of oxidation. The rate of curing may be increased by providing controlled humidity at higher temperatures. This process (steam curing) results in process wastewater.

After curing and prior to formation of plates, they may be soaked in sulfuric acid solution to enhance sulfation and improve mechanical properties. This may occur directly in the battery case or formation tank or in a separate vessel. In either case, no significant process wastewater results from this practice.

Semi-Assembly (Stacking, Grouping, Separator Addition) - Following curing, dry pasted plates are stacked or grouped in preparation for formation. This semi-assembly process varies depending, upon the specific formation process which is to follow and the type of separator being used.

Where formation is accomplished in the battery case (closed formation), positive and negative plates are stacked together with separators and welded to produce elements of an appropriate size for the batteries being produced. Separators may be interleaved between the positive and negative plates or wrapped around the positive plates.

Where formation is accomplished in open tanks, positive and negative plates are commonly grouped separately, spaced, and welded without separators. After formation, separators are added and positive and negative plates combined to form elements which are then inserted into the battery case.

Separators serve to prevent short circuiting between the anode and cathode while at the same time permitting electrolyte conduction between them. They also may serve to provide physical support to the positive plate. Both the configuration and material of separators vary depending on the specific properties desired. Materials used for separators in lead acid storage batteries include paper, plastic, rubber, and fiberglass. Sheet type separators which are interleaved between positive and negative plates are usually ribbed on one side. The ribbed side is placed against the cathode to provide for improved electrolyte transport. Other separators are flexible and are wrapped around the positive plate or are in the form of envelopes enclose the positive plates. Some separators are highly absorbent and retain large quantities of electrolyte preventing it from spilling from the battery.

Water use in the semi-assembly operation is limited to noncontact cooling water associated with welding of elements and groups. No process wastewater is produced.

Electrolyte Preparation and Addition - Sulfuric acid is purchased by battery manufacturers as concentrated acid (typically 93 percent) and must be diluted with water or "cut" to the desired concentration(s) prior to use in forming electrodes or filling batteries. Dilution commonly proceeds in two steps. Initially the acid is cut to an intermediate concentration (about 45 percent acid) which may be used in paste preparation. Subsequently final dilutions are made to concentrations (generally 20-35 percent) used in battery formation and battery filling. Often two or more different final acid concentrations are produced for use in formation and for shipment in different battery types. Acid cutting generates heat and generally

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requires non-contact cooling. Process wastewater, however, is not generally produced although wet scrubbers are used at some sites to control acid fumes. Since water is consumed in cutting acid, some facilities use this process as a sink for process wastewater contaminated with acid and lead, reducing or eliminating the volume requiring treatment and discharge.

For some batteries, sodium silicate is added to the electrolyte prior to addition to the battery to produce a thixotropic gel. The gel is poured into the battery and allowed to set, yielding a product from which liquid loss and gas escape during operation are minimal and which may be operated in any orientation.

The addition of electrolyte to batteries for formation and for shipment is frequently a source of wastewater discharge both directly in the form of acid spillage and indirectly in discharges from battery rinsing necessary to remove spilled acid from the battery case. Electrolyte addition is accomplished by a wide variety of techniques which result in widely varying amounts of spillage and battery case contamination. While efficient producers employ filling devices which sense the level of electrolyte in the batteries and add only the proper amount with essentially no spillage or case contamination, others continue to regulate the amount of acid in the batteries by overfilling and subsequently removing acid to the desired level. In some facilities, batteries are filled by immersion in tanks of acid. Overfilling or filling by immersion result in significant contamination of the battery case with acid and necessitate rinsing prior to further handling or shipment, generating significant volumes of process wastewater.

Formation (Charging) - Although lead peroxide is the active material of the finished positive plate, it is not used in preparing paste for the plate. The formation process converts lead oxide and sulfate to lead peroxide for the positive plate and to lead for the negative plate by means of an electric current. Formation starts in the region where poorly conducting paste is in contact with the more conductive grids and proceeds through the volume of the paste. Completion of formation is indicated by (1) color of active materials (plates have "cleared" and are uniform in color), (2) plates are gassing normally, (3) a constant maximum voltage is indicated, and (4) the desired electrolyte specific gravity is reached. Final composition for the positive plate is 85-95 percent lead peroxide and the negative plate is greater than 90 percent lead. Formation of battery plates may be accomplished either in open tanks prior to battery assembly (open formation) or within the battery case after assembly has been completed (closed formation). Open formation is most often practiced in the manufacture of dehydrated plate batteries.

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Open Formation. Open formation has the advantage of allowing access to the battery plates during and after formation. This permits visual inspection of the plates during formation and closer control of formation conditions than is possible during closed formation. More significantly, however, after open formation, plates may conveniently be rinsed thoroughly to remove residual electrolyte and efficiently dried as required for the manufacture of dehydrated plate batteries.

Most open tank formation is immediately followed by rinsing and dehydrating of the formed plates. These operations are particularly important for the (lead) negative plates which would oxidize rapidly if acid and moisture were not eliminated. Rinsing is accomplished by a variety of techniques and may involve the use of deionized water in some cases. Multi-stage rinses are frequently employed to achieve the required degree of electrolyte removal. Drying often involves the use of both heat and vacuum to achieve dehydration of the plates. Wastewater discharges result from vacuum pump seals or ejectors used in drying as well as from rinsing. Wastewater may also result from wet scrubbers used to control acid mist and fumes from charging tanks, but this source is generally small in comparison to rinsing and drying discharges.

Open tank formation may also be used in the manufacture of some wet batteries. Because problems in formation associated with inhomogeneity in the plates are most pronounced in larger plate sizes, open tank formation for the manufacture of wet batteries is most often encountered in the manufacture of industrial batteries with large electrodes. Since these electrodes do not require rinsing and drying however, open tank formation in these instances differs little from closed formation in terms of wastewater generation and entails only losses from drips and spills and, in some instances, discharge from wet scrubbers used for fume control.

Closed Formation. Closed formation is performed in several different ways depending upon the desired charging rate and characteristics of the final product. The major variations in this process may be termed: single fill-single charge, double fill-single charge, double fill-double charge, and fill and dump (for damp batteries). A major factor influencing the choice of operating conditions for closed formation is the relationship between charging rate, electrode characteristics, and electrolyte concentration. In general terms, as the electrolyte concentration is increased, the rate at which formation of positive plates proceeds is decreased, but durability of the product is improved. The rate of formation of negative plates is increased by increasing acid concentration.

In the single fill-single charge process, the battery is filled with acid of a specific gravity such that, after formation, the electrolyte will be suitable for shipment and operation of the battery. The rate

at which formation proceeds may vary appreciably with formation periods ranging from about one to seven days. During formation heat is generated in the batteries which must be dissipated. At the higher charging rates this may be accomplished using contact cooling water on the outside of the battery cases. This water is normally applied as a fine spray and may be recirculated reducing the volume of the resultant wastewater discharge. At lower charging rates, air cooling is sufficient, and this process water use is eliminated. Since hydrogen gas is often evolved during formation, wet scrubbers may be used to control sulfuric acid fumes and mist carried out by the gas. At lower charging rates, electrode over-voltage and consequently hydrogen generation is reduced minimizing the need for wet scrubbers.

Double fill formation processes involve the use of a more dilute formation electrolyte, formation of the battery in about 24 hours, removal of the formation electrolyte for reuse, and addition of more concentrated fresh electrolyte suitable for battery operation. Double fill-double charge batteries are subsequently given a second boost charge prior to shipment. As for single fill formation, contact cooling water is commonly used, and wet scrubbers may be required to control mist and fumes. Both filling and emptying battery cases may result in contamination of the case with acid necessitating subsequent rinsing. The extent of this contamination depends on the filling and emptying techniques applied.

The fill and dump process includes damp batteries which are a part of the group of batteries commonly called dry-charged by manufacturers. These differ from dehydrated plate batteries in the degree of electrolyte removal and dehydration. This causes the degree of charge retention during long-term storage to be less than the dehydrated plate type. These batteries are produced by closed formation of assembled batteries and subsequent removal of the electrolyte and draining of the battery which is shipped without electrolyte. After removal of the formation electrolyte, some manufacturers add chemicals to the battery in a second acid solution which is then dumped. These chemicals are intended to reduce the loss of battery charge during storage. Other manufacturers centrifuge or "spin-dry" the batteries before final assembly. Water use and wastewater discharge in the production of damp batteries do not differ significantly from that for double fill wet batteries.

Battery Assembly - As discussed previously, assembly may be partially accomplished prior to formation but is completed after formation. Assembly after open formation includes interleaving positive and negative plates and separators to create elements, installation of elements in battery cases, and welding connecting straps to the positive and negative lugs on the elements to provide electrical continuity through the battery. The battery cover is then installed and sealed in place by heat, epoxy, rubber cement, or with a bitu-

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minous sealer; vents are installed; and the battery posts are welded or "burned" in place. Partial assembly prior to closed formation is contiguous with semi-assembly and involves the same operations described above except that the creation of elements proceeds as described under semi-assembly. Final sealing of the case and installation of vent covers is accomplished after formation. In either case, no process water is used in assembly, and no process wastewater discharge results.

Testing - Most finished batteries are tested prior to shipment to ascertain correct voltage and current capacity. At some facilities a small volume of process wastewater may result. In addition, selected batteries may undergo more extensive tests including capacity, charge rate acceptance, cycle life, over-charge, and accelerated life tests. The conduct of these tests and subsequent disassembly and inspection operations may also yield a very small volume of wastewater which is similar in character to discharges from formation operations.

Batteries which are found to be faulty in testing may be repaired on site. These repair operations generally requiring disassembly of the battery and replacement of some component(s) may also generate a limited volume of process wastewater although this source is minor in relation to the total process wastewater flow.

Battery Wash - At most facilities batteries are washed prior to shipment to remove electrolyte slops resulting from spilling and splashing during filling and formation, and other contaminants resulting from assembly operations. Washing may be accomplished by hand or by battery wash machines and may involve the use of detergents to achieve more complete removal of dirt, oil and grease. Where detergents are used, the final battery wash containing the detergent may be preceded by a water rinse to remove lead and acid. Wastewater from battery rinses and from battery wash operations in which detergents are not used are treated and reused, or used in electrolyte preparation at some sites.

Process Integration - The differing means of implementing each of the basic process steps discussed above may be combined to produce a large number of distinct process flow sheets. Each facility will combine these process elements in a pattern suited to its age, type of product(s), degree of automation, and production volume. Further, not all facilities perform all process operations on-site. A significant number of plants purchase pasted battery plates from other facilities. Conversely, some battery manufacturing plants produce only battery plates and do not assemble finished batteries.

When plates are formed by the plate manufacturer prior to shipment only assembly and electrolyte addition are performed on-site by the battery manufacturer. Alternatively, the plates may be sold "green"

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(unformed) and subjected to either open or closed formation by the battery manufacturer.

Examples of wet, damp and dehydrated battery manufacture and of battery manufacture from purchased "green" and formed plates are shown in the process flow sheets of Figures V-11 through V-15 (Pages 203 - 207). In many cases, single facilities produce multiple product types and therefore have process flow sheets combining operations of more than one of these figures.

Subcategory Data Summary

Production - Lead acid battery production reported in dcp's totalled over 1.3 million kkg (1.43 million tons) per year. Of this total, 72.3 percent were shipped as wet batteries, 9.3 percent were damp, and 18.4 percent were produced as dehydrated plate batteries. Reported annual production of batteries at individual facilities in this subcategory ranged from 10.5 kkg (11.5 tons) to over 40,000 kkg (44,000 tons). Median annual production at lead subcategory plants was approximately 6,000 kkg (6,600 tons). No correlation between plant size and battery type i.e. wet, damp, or dry batteries was observed.

Geographically, lead acid battery plants are distributed throughout the U.S. and are located in every EPA region. The highest concentrations of plants in this subcategory are in EPA regions IV, V and IX. Region IX in particular contains large numbers of small manufacturers many of whom purchase battery plates from outside suppliers.

Water Use and Wastewater Discharge - Production normalized flows discharged (1/kg of total lead) from various process operations are presented in Figure V-16 (Page 208). This figure shows the distribution of production normalized flows for each process operation at those plants which produce a wastewater discharge for a process operation. Plants which report no process wastewater from the process are not represented on the curves as shown. The insert on the figure presents for each process the median of the non-zero flows, the median of all flow values, the total number of flow values, and the number of these which are equal to zero. The median shown for the non-zero flows is derived from a linear regression fit to the data and represents the best available estimate of the median flow from all plants discharging wastewater from each process operation. Because of the difficulty in handling zero values in this statistical treatment, the median shown for all values is the classical median of the sample population (plants supplying specific process flow data).

As the regression lines on the figure indicate, the dispersion in the flow data (as indicated by the slopes of the lines) showed no

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significant differences among different process operations. The median flows differed considerably. This reflects the fact that the variability in wastewater flow from all process operations results primarily from the same factors, i.e. plant-to-plant variations in the degree of water conservation and flow control practiced. No significant technical factors causing major wastewater flow differences were identified for any of these process elements and none are indicated by these data. Consequently the data indicate that any plant active in any of these process operations can achieve wastewater flows demonstrated for that process by other facilities without any major process change.

As the insert on Figure V-16 shows, there are significant differences among different process operations in the frequency with which zero wastewater discharge results. Five of the eight processes shown are reported to produce zero process wastewater by over half of the plants supplying data. Zero process wastewater is reported by fewer than 20 percent of the plants supplying data for the other three process operations.

In open case formation for batteries which are shipped wet, five plants reported no formation process wastewater, while the other two showed very high process discharges comparable to those from plate formation and dehydration processes used in producing dehydrated batteries. An examination of manufacturing process information at these two facilities reveals that they are in fact, producing formed dehydrated electrodes prior to including them in wet-charged batteries. Thus, all facilities practicing open case formation without rinsing and dehydrating the formed electrodes presently report zero process wastewater discharge from this operation.

Closed formation of wet batteries was reported to produce a process wastewater discharge at 31 of 88 plants supplying information. Both single fill and double fill formation are included. Data from those facilities from which data specific to these two formation processes was obtained are summarized in Figure V-17 (Page 209). As these data show, 90 percent of all plants reported zero discharge from single fill formation while over 75 percent reported wastewater discharge from double fill formation. The median flow at discharging plants, however, was approximately equal for both processes. The more frequent discharge of process wastewater from double fill formation is attributable to more frequent use of contact cooling water in formation as well as rinsing of batteries after dumping formation electrolyte.

Process water from leady oxide production was reported by twelve facilities, ten of which were operated by two companies. Waste was reported to originate in leakage and "shell cooling" on ball mills, contact cooling in oxide grinding, and wet scrubbers used for air

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pollution control. Most plants perform these processes using only noncontact cooling water and dry bag-houses for air pollution control and consequently produce no process wastewater.

Fifty-one of seventy plants supplying data produce no process wastewater discharge from electrode pasting operations. This is accomplished by treatment and recycle of pasting wastewater which is common practice through the subcategory.

Process wastewater discharge from curing operations is reported by fewer than 10 percent of the plants supplying data (8 of 89 facilities) and results from steam curing processes. Predominant industry practices of curing in covered stacks or in humidity controlled rooms achieve equivalent results to steam curing and produce no wastewater. Mean and median discharge flows for each process operation in this subcategory are presented in Table V-31 (Page 285).

Total plant discharge flows range from 0 to nearly 62,000 l/hr with a median value of 3,500 l/hr. Production normalized discharge flows range from 0 to 100 l/kg with a median of 2.8 l/kkg. Discharge flow from each plant in the subcategory is shown in Table V-32 (Page 286). Approximately 27 percent (50 plants) of all plants in the subcategory reported zero process wastewater discharge to POTW or surface waters. These zero discharge facilities were primarily either plants which purchased plates and assembled batteries only (17 plants) or plants which produced only wet batteries and generally employed single-fill formation (18 plants). Of the 50 plants, 26 plants indicated that no process wastewater was generated. Six others indicated that wastewater was recycled and reused. The remaining facilities employ evaporation or holding ponds (5 plants), discharge to dry wells, sumps, septic tanks or cesspools (9 plants), contract removal of process wastewater (2 plants), disposal of wastes in a sanitary landfill (1 plant), or did not specify the disposition of process wastes (1 plant). Among discharging plants, only sixteen were direct dischargers. All others introduce process wastewater into POTW.

Wastewater Treatment Practices and Effluent Characteristics - Plants in the lead subcategory employ a variety of end-of-pipe treatment technologies and in-process control techniques and achieve widely varying effluent quality. End-of-pipe treatment practices employed include pH adjustment, chemical precipitation, settling in a variety of devices, filtration, flotation, and reverse osmosis. In-process control techniques include segregation and treatment or recycle of specific waste streams and process modifications to eliminate points of water use and discharge. Discharge to POTW is performed by most plants in the subcategory which produce a process wastewater discharge. Dcp responses showed some significant differences between plants discharging to POTW and direct dischargers both in terms of

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treatment practices and effluent performance achieved. Direct dischargers generally provide more extensive wastewater treatment and control facilities than plants discharging to POTW. Where similar treatment equipment is in place, direct dischargers generally operate it more effectively and achieve better effluent quality.

The most frequently reported end-of-pipe treatment systems in this subcategory provided pH adjustment and removal of solids. Fifty-seven plants reported the use of pH adjustment and settling while nineteen others reported the use of filtration for solids removal. Reported filtration units generally serve as primary solids removal and are not polishing filters designed to achieve very low effluent pollutant concentrations.

Effluent quality data provided in dcp's for plants practicing pH adjustment and settling are presented in Table V-33 (Page 289). While the dcp's did not in general provide sufficient data to allow meaningful evaluation of treatment system design and operating parameters, some characteritics of the effluent data themselves provide indications of the quality of treatment provided and of the probable sources of the variability shown. First, the limited effluent pH data provided in the dcp's indicates that few discharges are at values (pH 8.8-9.3) appropriate for efficient removal of lead by precipitation. In the data from those plants reporting both lead and pH in the effluent, it may be observed that those plants reporting higher pH values achieved lower effluent lead concentrations. Second, effluent TSS values shown in Table V-33 clearly indicate that the sedimentation systems employed by some facilities are inadequate in design or operation. Finally, plants which introduce their wastewater into POTW produced effluents ranging from 0.5 mg/l to 7.5 mg/l in lead concentration with an average of 2.1 mg/l. Plants discharging to surface waters and also practicing pH adjustment and settling produced effluents ranging from 0.187 to 0.4 mg/l with an average of 0.28 mg/l. The great difference in effluent performance between these two groups of plants corresponds to differences in the severity of regulations presently applied to direct and indirect discharges, indicating that the variations in the data reflect variations in treatment design and operating practice rather than difference in attainable levels of pollutant reduction at these facilities.

Table V-34 (Page 290) presents effluent quality data from dcp's for plants practicing pH adjustment and filtration. In general, the indicated effluent pollutant concentrations are lower than those shown from pH adjustment and settling, and the variability in the data is less marked. The effluent data from these systems also show lower lead concentrations achieved by plants practicing direct discharge.

Twenty-two plants reported the introduction of process wastewater into POTW after pH adjustment without the removal of suspended solids.

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Effluent quality data were provided by eleven of these facilities as shown in Table V-35 (Page 291). This table also shows effluent data from one facility which reported process wastewater discharge to a POTW without treatment.

Several plants provided data in dcp's indicating the use of wastewater treatment systems other than those discussed above. These included sulfide precipitation, flotation separation, and reverse osmosis. One facility practicing chemical precipitation and flotation separation of the precipitate reported an effluent lead concentration of 0.1 mg/l.

While most plants specified end-of-pipe treatment in their dcp responses, in-process controls were often not clearly shown and were only indicated by process line descriptions and identified wastewater sources similar to those of plants visited for on-site data collection. As a result, the present extent of practice of such techniques as low-rate charging without the use of contact cooling water cannot be defined from the dcp's. One in-process control technique which could be identified in many dcp's was segregation of process wastewater from pasting area and equipment washdown and subsequent settling and reuse of this waste stream. Approximately 30 percent of the plants reporting wastewater discharges indicated this practice. Those facilities using this in-process technique are identified in Tables V-33, V-34, and V-35. The data in Tables V-33 and V-34 do not show significantly lower effluent lead concentrations from plants recyling pasting wastewater although raw waste concentrations and pollutant loads are significantly reduced by this practice as demonstrated by the data in Table V-35. This further substantiates the observation that effluent quality at existing lead subcategory plants is primarily determined by treatment system design and operating parameters.

Additional in-process control techniques which are indicated in the dcp's include: recirculation of wet scrubber discharge streams; use of multistage or countercurrent rinses after open formation; reduction or elimination of electrolyte spillage during battery fill operations or dry cleanup of spilled electrolyte; slow rate charging of assembled batteries without the use of contact cooling water; and elimination or recirculation of vacuum pump seal water or vacuum ejector streams in plate drying operations. Recirculation of wet scrubber discharge streams is specifically reported in some dcp's and is presumed to exist at other facilities since many plants report no scrubber discharges although acid mist and fume problems are common to most manufacturers. Multistage or countercurrent plate rinses are identified by approximately 30 percent of those facilities which practiced dehydrated plate manufacture and supplied process diagrams in their dcp's. The production normalized flow resulting from these rinses are not generally significantly lower than those resulting from single stage or unspecified rinses. Since the spillage of electrolyte

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on battery cases necessitates removal of the spilled acid prior to shipment to allow safe handling of the battery, it may be concluded where wet batteries are shipped and battery wash discharges are not reported, that spillage has been eliminated, or that any spillage which has occurred has been neutralized and cleaned up by dry techniques. Both of these conditions have been observed, and a small but significant number of battery manufacturers reported shipment of wet batteries and provided complete process diagrams which did not show battery wash wastewater production. The use of slow-rate charging is indicated at a number of battery manufacturing facilities which did not indicate process contact wastewater from wet-charge formation processes. Finally, approximately 50 percent of the plants which supplied complete process diagrams describing open case formation and subsequent rinsing of the formed plates prior to assembly into dehydrated plate batteries showed no wastewater from pump seals or vacuum ejectors on plate drying and no other process wastewater sources associated with plate drying. It is concluded that these facilities either achieve satisfactory plate drying without the use of seal or ejector water or recirculate water used for these purposes.

Process Water Uses and Wastewater Characteristics

Process wastewater was characterized by sampling at five facilities manufacturing lead acid batteries. These plants collectively represent the production of both SLI and industrial batteries and manufacturing processes including single and double fill closed formation processes and the formation of damp and dehydrated plate batteries. They also embody a variety of in-process control techniques including pasting washdown recirculation, low rate formation, and recirculation of treated process wastewater, and several different wastewater treatment technologies. Sampling at these facilities provides the basis for characterizing total battery manufacturing process wastewater and wastewater resulting from specific process operations. Interpretation of sampling results is enhanced by reference to additional information obtained from industry dcp's and in visits to eleven additional lead acid battery manufacturing facilities at which wastewater samples were not obtained.

Total Process Wastewater Characteristics - Total process wastewater characteristics determined from the analysis of samples collected at Plants A, B, C, D, and E are presented in Table V-36 (Page 292). Pollutant loads determined by sampling at each of these facilties are presented in Table V-37 (page 294). These data represent the process wastewater stream discharged to treatment at each facility. All process waste sources flowing to treatment are included, but streams which are totally recycled such as pasting wastewater are not included in these data. Considerable variations in wastewater volume and in

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pollutant concentrations and loadings among these facilities are evident. They may be understood on the basis of the manufacturing processes and wastewater management practices at these sites.

Plant A manufactures wet and damp batteries and practices extensive in-process control of wastewater. Pasting equipment and area washdown at this facility is treated in a multistage settling system and totally reused. The clarifier supernatant from this system is reused in equipment and area washing, and the settled lead oxide solids are returned for use in pasting. Batteries are formed at this site using the double fill-double charge technique, filling operations are performed using equipment designed to avoid electrolyte spillage and overfilling, and formation is accomplished without the use of contact cooling water. Wastewater associated with formation is limited to a spray rinse of the battery case after the final acid fill. Wet charged batteries are boost charged one or more times before shipment and given a final wash just before they are shipped. Damp batteries at this site are initially formed in the same manner as wet batteries. The second acid fill, however, is also dumped for reuse, and the battery is sealed and spray rinsed. These damp batteries are given the same final wash prior to shipment as the wet charged units. A small volume of additional process wastewater at this site results from cleanup operations in a reject battery repair area. The total waste from this facility which is represented in Tables V-65 and V-66 includes wastewater flowing to waste treatment, the battery rinses and wash water, and the repair area clean-up waste, but does not include the pasting wastewater since this stream is segregated and totally recycled. The low pollutant concentrations and loadings shown in the table reflect the efficiency of the in-process controls employed by this facility. Significantly, the wastewater treatment system includes an evaporation pond allowing the achievement of zero pollutant discharge from this facility.

Plant B manufactures a high percentage of dehydrated plate batteries but also practices significant in-process control techniques. Pasting equipment and area wash water is recirculated using a system similar to that described at Plant A. Wet batteries are produced in a single fill formation process, which is accomplished using low rate charging to eliminate process contact cooling water, and filling techniques which minimize battery case contamination. Only occasional discharges result from filling area and battery case washing. Open-case formation and plate dehydration operations account for most of the process wastewater generated which results from plate rinsing, fume scrubbers, formation area washdown, and from a vacuum ejector used in dehydrating the formed, rinsed plates. Partially treated wastewater is recycled from the waste treatment system for use in the wet scrubbers, area washdown, and rinsing formed plates, but recycled water is not used in the vacuum ejectors. As a result of the recycle practiced, the volume of the final effluent from this facility is only

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46 percent of the raw waste volume shown in the table or approximately 4.0 l/kg.

The raw waste characterized in the table includes process wastewater from open formation and plate dehydration, closed formation processes and contaminated wastewater resulting from a cooling jacket leak on a ball mill used in producing lead oxide but it does not include pasting wastewater which is totally recycled. The effect of plate rinsing operations in the open formation process is evident in the elevated lead concentrations and loadings at this facility. The relatively high production normalized flow results to a great extent from the use of large volumes of water in ejectors to aid vacuum drying of the rinsed plates.

Plant C produces wet and damp SLI batteries and practices only limited in-process controls. Pasting area wash water is collected in a sump and pumped to the plants' central wastewater treatment facility. Aside from limited settling of the heaviest material in the sump, this waste stream is neither recycled nor treated separately prior to combining with other process waste streams. Wet and damp batteries both undergo an initial high rate formation process in which contact cooling water is sprayed on the battery cases and discharged to waste treatment. The wet batteries are subsequently dumped (the acid is reused) and refilled with stronger acid, boost charged, and topped off to ensure the correct electrolyte level. Damp batteries are dumped after formation and centrifuged to insure complete electrolyte removal. Wastewater from the centrifuge including some formation electrolyte also flows to wastewater treatment. Both the wet charged and damp batteries are washed, labeled, and tested prior to shipment. Wastewater from battery washing also flows to treatment.

The combined raw waste at this facility was sampled as it entered wastewater treatment and includes all sources discussed above. The pasting wastewater is represented in process wastewater characteristics presented for this plant. This, together with differences in water conservation practices, appears to account for the differences observed in pollutant concentrations and waste loads between this facility and Plant A. Lead pollutant loadings, for example, are significantly higher at Plant C as a result of the introduction of pasting wastewater and wastewater from battery centrifuges into waste treatment, but raw waste concentrations are low due to the dilution afforded by the much higher wastewater volume at this facility (approximately 8 times greater production normalized flow).

Plant D manufactures both SLI and industrial batteries and employs closed and open formation processes. Several in-process control techniques at this facility resulted in the generation of a relatively low volume of process wastewater. Pasting area and equipment wash

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water is not recycled at this facility, but is separately treated by settling before introduction into the plant's wastewater treatment system. Closed formation of SLI batteries is accomplished in a double fill process without the use of contact cooling water. The final acid fill after formation is followed by a battery rinse yielding a process wastewater discharge. No industrial batteries were formed during sampling at this facility. Open formation is followed by a two-stage countercurrent rinse of the formed plates. They are dried in an oven without the use of any ejector or vacuum pump seal water. Finished batteries are given a final wash prior to packaging and shipment. Additional sources of process wastewater at this site include assembly area washdown, reject battery repair operations, and wastewater from an on-site laboratory.

Plant E manufactures only wet industrial batteries. In-process control techniques at this site reduce the ultimate discharge volume essentially to zero. Formation is accomplished in a single fill process using low rate charging. No contact cooling water is used and batteries are not washed. Process wastewater at this facility results only from washing pasting equipment and floor areas. This wastewater is treated and recycled for use in washing pasting area floors. Equipment is washed using deionized water resulting in a gradual accumulation of wastewater in the recycled system and necessitating occasional contract removal of some wastewater. The total process wastewater characterized in Tables V-36 and V-37 includes the wastewater from pasting equipment and area washdown. The sample used to characterize this waste was obtained from a waste collection pit in which settling of paste particles occurred resulting in the reduced lead and TSS concentrations observed. The total process wastewater characteristics presented in Tables V-36 and V-37 were calculated from analyses of all of the individual waste streams described above including the pasting wastewater before settling.

A statistical summary of the total raw waste characteristics observed at these facilities is presented in Table V-38 (Page 296). This table shows the range, mean, and median concentrations observed for each pollutant included in verification analyses. Corresponding pollutant loading data are presented in Table V-39 (Page 297).

Wastewater From Specific Process Operations - Wastewater samples obtained at a number of facilities provide characterization of wastewater from specific process operations which contribute to the total wastewater stream addressed in the preceding discussion. Major process wastewater sources characterized include pasting, closed formation for wet batteries, closed formation for damp batteries, open formation and plate dehydration for dry charged batteries and battery wash operations. Wastewater from battery repair operations and general plant floor washing was also characterized in sampling

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although these sources constitute minor contributions to the total process wastewater flow.

Characteristics of individual process waste streams from the major wastewater sources are summarized in Table V-40 (Page 298) which also provides the range and median values of concentrations in these individual waste streams.

Pasting. Wastewater samples were taken at three plants. Analysis results are shown in Table V-41 (Page 299). As indicated on the table, wastewater samples at two facilities were obtained from sumps or holding tanks in which some settling of solids from the pasting waste evidently occurred. A sample of the supernatant from an in-line settling tank at Plant D was found to contain 10 mg/l of suspended solids and 37 mg/l of lead indicating that significant reduction in suspended solids and lead is attained by settling. Since the waste stream sampled at Plant A has minimum settling effects, it was chosen as typical of raw wastes developed by this process for the determination of typical raw waste characteristics as shown in Table V-69. Pollutant loads from pasting based on sampling results at that facility are shown in Table V-42 (Page 300). This process is potentially a major contributor to total raw waste loads but may be eliminated by recycle as presently practiced at many sites.

Closed Formation of Wet Batteries. Wastewater samples were obtained at Plant A and represent the post formation rinse of double fill wet batteries. Contact cooling water used in formation was included in the total process wastewater at Plant C but was not separately characterized. Production normalized wastewater flows associated with formation of wet batteries at Plant A are comparable to the median value found in the dcp's. Formation wastewater characteristics and pollutant loads observed in sampling at this site are presented in Tables V-43 and V-44 (Pages 301 and 302) respectively.

Closed Formation of Damp Batteries. Wastewater samples were also obtained at Plant A. This process replaced a conventional dehydrated plate system in which it was necessary to remove the cells and run them through a high water use three stage washer. The discharge is associated with a spray rinse similar to that used for wet formation. Loadings are somewhat higher than those for wet formation, apparently as a result of case contamination in dumping electrolyte from the batteries.

Damp batteries are also produced at Plant C, and wastewater from formation of these units is included in the total raw waste stream sampled at that facility. Formation wastewater at that site results from contact cooling of batteries during a high rate formation process.

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Formation and Dehydration of Plates. Plant D uses countercurrent rinsing of the open case formed electrodes and uses no ejector or pump seal water in plate dehydration. Despite those practices, wastewater discharge from plate formation and dehydration at this site is higher than the median value from dcp's. This may be attributed to the low volume of dehydrated plate production and inefficient control of water used in the plate rinse. Concentrations observed in wastewater from this step (shown in Table V-45, Page 303) are similar to those observed in wastewater from other processes. Pollutant loads from open formation and dehydration of electrodes are shown in Table V-46 (Page 304). An indication of discharge characteristics from open formation where water is used both in rinsing and dehydration may be derived from the total process wastewater at Plant B which is dominated by discharges from open formation processes.

Battery Wash. Battery wash wastewater sample results from Plants A and D are presented in Table V-47 (Page 305). Sampling at Plant D included both a battery rinse and a final detergent wash. Samples from Plant D also include small flow contributions from battery testing and area washdown. Table V-48 (Page 306) presents pollutant loads observed in sampling at these sites.

Battery Repair and Floor Wash. Wastewater samples were obtained at Plant A. Analysis results are shown in Table V-49 (Page 307), and corresponding waste loads are shown in Table V-50 (Page 308). The samples represent waste from a floor washing machine and from cleanup associated with a battery repair area. As the data show, contributions of these waste sources to the total plant process wastewater are minimal.

Additional Wastewater Sources. Battery manufacturers reported some process wastewater streams which were not characterized by sampling. Some, such as lead casting wastewater and wastewater from plastic molding operations, were excluded from consideration because they are not included in the battery manufacturing category. Process contact wastewater from leady oxide production in ball milling is a rare occurrence, resulting from inadequate maintenance or air scrubbers. This process wastewater stream was not specifically characterized by sampling, however, contributions to total wastewater flow are minimal.

Wastewater from curing pasted plates by steaming is reported at a number of facilities but was not observed at any plants visited for wastewater sampling. This wastewater stream is, however, small in volume and will have little effect on wastewater treatment design and performance. It is anticipated that chemical characteristics of wastewater from this source will be similar to those found in rinse wastewater from dehydrated plate manufacturing.

Treated Effluent Characteristics - The characteristics of treated
effluent discharges at three visited battery manufacturing plants are
presented in Table V-51 (Page 309). These facilities all employ waste
treatment systems based on chemical precipitation and solids removal
but have implemented three different solids removal techniques.

Plant B employs a tubular cloth filter from which solids are
continuously removed by the flow of the waste stream which becomes
progressively more concentrated as clarified water permeates through
the filter. This system is reported to be highly effective as
indicated in dcp data from this facility. During sampling, however,
excessive solids levels had been allowed to build up in the system and
were observed to be carried through the filter during surge flows. As
a result, effluent characteristics determined in sampling do not
reflect effective treatment. Plant C employs a clarifier followed by
a polishing lagoon for wastewater treatment. As the data show, this
system was operating normally during sampling and produced the lowest
lead levels observed in sampling.

At Plant D, wastewater is treated by pH adjustment and subsequent
filtration through a diatomaceous earth pre-coat filter press. During
the plant visit, company personnel acknowledged that the plant
production and wastewater flow rates had increased and that the system
was therefore overloaded. This condition is reflected in observed
effluent performance which was considerably worse than that exhibited
in historical data from the facility.

Data from these facilities illustrate the importance of pH as an
operating parameter for the removal of lead by chemical precipitation.
Both plants B and D were observed to provide treatment at pH values
considerably lower than is desireable for lead precipitation, a
condition reflected in the poor effluent performance observed in
sampling. This effect is particularly evident on day 1 at plant D
when the effluent pH was observed to be as low as 6, and a comparison
of effluent lead and TSS values shows clearly that the effluent
contained considerable concentrations of dissolved lead.

LECLANCHE SUBCATEGORY

This subcategory encompasses the manufacture of all batteries
employing both a zinc anode and a zinc chloride or zinc chloride-
ammonium chloride electrolyte. Presently there are 19 active plants
in the subcategory, 17 of which manufacture cells with zinc anode,
carbon-manganese dioxide (MnO_2) cathode, and zinc chloride or zinc
chloride-ammonium chloride electrolyte. The remaining two plants use
a silver cathode. There are several distinct variations both in form
and in manufacturing process for the Leclanche cell, with
corresponding variation in process water use and wastewater discharge.
Wastewater discharge results only from separator production and from

cleanup of miscellaneous equipment. After a discussion of the manufacturing processes employed in the subcategory and a summary of available data characterizing Leclanche subcategory facilities, the process elements that produce wastewater are discussed in greater detail regarding specific wastewater sources, flow rates, and chemical characteristics.

Manufacturing Processes

As shown in the generalized process flow diagram of Figure V-18 (Page 210), the manufacture of batteries in this subcategory comprises the preparation of the anode and cathode, the preparation or application of the separator, assembly of these components into cells and batteries, and ancillary operations performed in support of these basic manufacturing steps. Process water is used in separator preparation, electrolyte formulation, and in a variety of ancillary operations. Process wastewater results from ancillary operations including the preparation of some types of separators.

The observed variations in anode, cathode, and separator manufacture and the combinations of these processes carried out at existing plants and ancillary operations that have been observed to generate wastewater are shown in Table V-52 (Page 311). These variations provide the framework for analysis of process wastewater generation in the Leclanche subcategory as indicated in Figure V-19 (Page 211). Of twelve identified process elements in this subcategory, only four generate process wastewater. Three of these were characterized by wastewater sampling at two facilities in the subcategory. Wastewater discharge from the fourth is believed to be similar in character, and is eliminated by recycle in present practices.

Anode Manufacture - The Leclanche anode is produced either from zinc sheet or powdered zinc. The zinc sheet is most often formed into a can, which contains the other components of the cell. This can is either purchased, or formed at the battery plant. The forming processes may involve cleaning and chromating steps that generate wastewater; however, these processes are not considered to be part of battery manufacturing. The other form of zinc sheet metal anode is a flat zinc plate.

Preparation of powdered zinc anodes includes formulation of an anode paste of zinc dust, carbon, and binders. The paste is applied to specific areas on a conductive vinyl film.

Cathode Manufacture - Four distinct types of cathodes are produced in the Leclanche subcategory; cathodes molded from mixed manganese dioxide and carbon with several variations in electrolyte form, porous carbon cathodes (which also contain manganese dioxide), silver chloride cathodes, and cathodes in which manganese dioxide is pasted

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on a conductive substrate. These cathode types are combined with zinc anodes and electrolyte to yield cells with a variety of configurations and performance characteristics.

Powdered MnO_2 cathodes are produced by blending manganese dioxide with other powdered materials consisting primarily of carbon. The resulting mixture is then combined with electrolyte solution before insertion into the cell. Manufacture of this type of cathode is reported by 14 plants. One of these discontinued operations during 1979, leaving 13 active plants. Based on both the survey and visit data, the list of raw materials added to the manganese dioxide ore to form the cathode may include acetylene black, carbon black, graphite, magnesium oxide, mercury, and ammonium chloride. Typically, ammonium chloride is added to the electrolyte solution prior to blending with the depolarizer material; however, one plant reported that ammonium chloride is added directly to the depolarizer material. After preparation of the depolarizer material, the electrolyte solution, which may or may not contain mercury, is added. (In Leclanche cells, mercury is added to either the electrolyte, cathode mix, or the separator). Five out of the thirteen plants reported adding mercuric chloride to the electrolyte solution. Nine plants reported combining the depolarizer material with an electrolyte solution which does not contain mercury. One plant is counted in both groups because both manufacturing systems are used in the plant.

Porous carbon cathode manufacture consists of blending carbon, manganese dioxide, and water; molding this mixture around a porous carbon rod; wrapping in a nylon net separator; and drying in an oven. This agglomerate electrode is sometimes called an "agglo".

The silver chloride cathode is prepared by molding silver chloride around a silver wire to form a bobbin. After wrapping, the cathode bobbin is ready for insertion into the zinc anode can. Two plants reported the manufacture of silver chloride cathodes.

For the pasted MnO_2 cathode, a paste consisting of manganese dioxide, carbon, and latex is applied to a conducting film. The steps used to prepare similar to the steps this film are described above for the zinc powder anode. The cathode paste material is applied on the film in rectangular spots, directly opposite the anode spots. Anode and cathode preparation utensil washwaters are combined, and the resulting wastewater is included under ancillary operations.

Ancillary Operations

Separator Manufacture - Separators are used to isolate the cathode from the anode, while providing a conductive path between them. Separators consist of gelled paste, treated paper, or plastic sheet.

Wastewater is directly associated with the manufacture of some of the Leclanche separators.

Cell Assembly - Cell assembly processes differ for paper separator cells, paste cells, flat cells, carbon cathode cells, silver cathode cells, and pasted cathode cells. In making paper separator cells, a pre-coated paper separator is first inserted into the zinc can. The depolarizer mix is compacted into a cylinder, the carbon rod (current collector) inserted into the mix and the subassembly inserted into the paper-lined can. Additional electrolyte and paper washers are added before the cell is sealed. A cap and paper collar are attached to the cell, and the cell is tested and aged. Cells are then either sold separately or combined and assembled into batteries, tested again, and packed for shipment.

In paste cell production, a paste containing water, flour, starch, zinc chloride, mercuric chloride, and ammonium chloride is inserted into a zinc can. The depolarizer-electrolyte mix, molded around a central carbon rod, is inserted into the zinc can. After the paste sets into a gel, the cell is sealed. The cell then goes through testing, finishing, aging, and retesting before being packed and shipped. The processes of conveying the cathode bobbin to the cell assembly and of setting the separator paste result in the generation of process wastewater in one type process. These processes are discussed in greater detail in subsequent portions of the section.

In flat cell production, the major operations include the manufacture of the duplex electrodes and depolarizer-electrolyte mix cake, cell assembly, and battery assembly. The duplex electrode is made by coating one side of a zinc sheet with conductive carbon. Manganese dioxide, carbon, ammonium chloride, zinc chloride, and water are mixed and pressed into a cake which serves as a depolarizer and electrolyte. The duplex electrode and the cake are then stacked together with a paper separator in between and a plastic envelope around the four sides of the cell. The cells then undergo a quality control inspection and are assembled into stacks with a final flat zinc electrode and tin plated steel end boards. The stacks are inspected, dipped in wax, aged, and inspected again for quality assurance. Stacks are then assembled into finished batteries.

In assembling the porous carbon cathode cell, the porous carbon cathode is inserted into the zinc anode container. An electrolyte-separator paste is then added, and the cells are sealed and interconnected to form batteries.

In the silver chloride cathode cell, the wrapped cathode bobbin is inserted into a zinc can containing the electrolyte-separator paste. The cell is then sealed.

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The powdered zinc anode-pasted MnO_2 cathode foliar cell is assembled by interleafing separator sheets between the duplex electrodes and adding electrolyte before sealing the cells into a stack. The sealed stack of cells is tested and wrapped to form a finished battery.

Equipment and Area Cleanup - In the Leclanche subcategory, there are equipment cleanup practices that cannot be associated with production of only one of the major cell components, anode, cathode, or separator. They include the clean-up of equipment used in assembling cells as well as in the preparation and delivery of electrolyte. Because wastewater results from some of these operations, they are discussed as ancillary operations.

Subcategory Data Summary

Nineteen plants are currently producing cells in the Leclanche subcategory. Most of the cathodes are made from MnO_2 and carbon, although two plants make cells with silver chloride cathodes. Cells with silver chloride cathodes, however, comprise less than 0.01 percent of the total production in the subcategory. Nearly all of the production is in the form of standard, round "dry cells". Other products are cells of various shapes for special purposes, flat cell, batteries, foliar film pack batteries, and air-depolarized batteries.

Production - Annual production reported in the subcategory totaled 96,260 kkg (106,108 tons). This total includes all except two plants (making carbon cathode and silver cathode cells, respectively) for which production is judged to be far below average for the subcategory. The total production also includes one high production plant which has discontinued operation (the production is believed to have been shifted to another plant owned by the company). Reported production is based on 1976 annual production rates, except for one plant which was not in production until 1977. Annual production at individual plants in the subcategory ranges from 1.4 kkg (1.5 tons) to 24,000 kkg (26,000 tons) with a median value of 2,700 kkg (3,000 tons).

Geographically, plants in the Leclanche subcategory are in the eastern United States, with a single exception in Texas. There are eight active facilities in EPA Region V, three each in Regions I and III, two each in Regions II and IV, and one in Region VI. The age of these facilities ranges from three years to many decades.

Raw Materials - Raw materials common to many of the plants in the Leclanche subcategory are zinc for anodes, MnO_2 and carbon for the cathode mix, carbon for the cathode current carrier, ammonium chloride and zinc chloride for the electrolyte, paper for the separator and paperboard washers, mercuric chloride for anode amalgamation, and asphalt for sealing. Other reported raw materials are zinc oxide,

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titanium, ammonium hydroxide, phenolics, manganese, adhesives, ammonia, polystyrene, steel, brass, ethyl cellulose, polyvinyl chloride, toluene, polycyclopentadiene, monochlorobenzene, cyclohexanone, silica, starch, solder, wax, grease, magnesium perchlorate, barium chromate, lithium chromate, latex, vinyl film, aluminum, magnesium oxide, and others.

Water Use and Wastewater Discharge - Process water use and wastewater discharge among Leclanche subcategory plants were generally observed to be very low or zero, with a maximum reported process water discharge rate of 2,158 1/hr. The only discrete cell component with which wastewater could be associated was with the separator. At several Leclanche plants, water is used for cleaning utensils or equipment used in the production of cell components rather than for cleaning the components themselves.

Eleven of the nineteen Leclanche subcategory plants reported zero process wastewater discharge. Two of the remaining plants did not report process wastewater flow rates. Process wastewater flow rates reported by the remaining six plants follow:

	Observed Flow Rate (1/day)	
Plant Number	Survey Data	Mean Visit Data
A	30.4	
B	9,900	5,340
C	0.47	
D	187	653
E	34,500	
F	1,910	

Mean and median discharge flows for each of the process operations or functions included in this subcategory are shown in Table V-53 (Page xxx). This table also presents the production normalizing parameters upon which the reported normalized flows are based.

Wastewater Treatment Practices and Effluent Quality - Only five of the 19 active plants in the Leclanche subcategory have wastewater treatment systems. The most frequent technique was filtration, which was reported at four plants. Three plants reported pH adjustment, two reported coagulant addition, two reported settling, two reported equalization, two reported coagulant addition, one reported skimming, and one reported carbon adsorption.

Table V-54 (Page 313) shows reported effluent quality at the Leclanche plants. Comparing this table with the treatment system information

shows that treatment, as practiced, has not always been very effective. Plant F, which reported high mercury and zinc effluent concentrations as shown in this table, also reported one of the more substantial treatment systems including amalgamation, pH adjustment, coagulant addition, and filtration.

Specific Process Water Uses and Wastewater Characteristics

Anodes - There is no process wastewater associated specifically with Leclanche anode manufacture.

Cathodes - There is no process wastewater associated specifically with Leclanche cathode manufacture.

Ancillary Operations

Cooked Paste Separator - In cells produced using this process, the paste temperature is elevated to achieve optimum setting conditions for the paste formulation. The raw materials for producing the paste include starch, zinc chloride, mercuric chloride, and ammonium chloride and water. After the paste and cathode are inserted into the zinc can, the can is passed through a hot water bath with the water level approximately one inch above the bottom of the can, heating the can and causing the paste to gell. After setting the paste, the can is removed from the hot water bath and final assembly operations are conducted.

Only one plant reported producing "cooked" paste separator cells. Wastewater from the paste separator manufacture was sampled at this facility. The only source of direct process discharge is from the hot bath paste settling. At this facility, no wastewater is discharged from either the paste preparation or paste clean-up operations, due to in-process controls. The paste preparation water supply tank holds water previously used for cleaning. The sources of water reused in mixing the paste include floor wash water from the paste preparation room, paste pipeline system wash water, and paste cleanup water used during mechanical difficulties. An example of mechanical difficulties is bobbin insertion failure which results in the paste being washed out of the cans for the purpose of recovering the cans for reuse. All of the water that contacts the paste is collected for reuse in paste formulation, and this closed system limits mercury contamination of the wastewater.

The source of direct process wastewater discharge is the hot bath used for setting the separator paste which becomes contaminated from contact with the outside of the can, from an occasional spill of one or more cans into the bath and wastes from the operating machinery.

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Total discharge rates measured during the sampling visit ranged from 0.03 to 0.05 liters per kilogram of finished cells, with a mean value of 0.04 and a median value of 0.05 l/kg. Composite samples were taken which include wastewater from each of the three discharge sources and the analytical results are presented in Table V-55 (Page 314). Table V-56 (Page 315) presents the pollutant mass loadings based on the weight of finished cells for each of the three sample days. Three significant pollutants found in this flow-proportioned combined waste stream are mercury, manganese and zinc. Also, TSS is present in significant concentrations which indicates material contamination from both paste and bobbin application. An additional significant pollutant in the paste setting wastewater is oil and grease. The primary source of this pollutant is drag-out water that contacts the lubricated gears that drive the tank conveyor.

Uncooked Paste Separator - Paste formulations are currently used in which the paste separator material sets at room temperatures. The wastewater from preparing these paste mixtures is substantially less than for the cooked paste method, and the separator characteristics are adequate for the cell types being produced. One plant manufactures carbon-zinc cells with an uncooked paste separator.

The paste formulation includes zinc chloride, ammonium chloride, mercuric chloride, cornstarch, and flour. The resulting paste is held in cold storage until injected into the zinc anode cans. After the insertion of the compressed cathode, the paste is then allowed to set. Next, the final assembly operations are performed to prepare the cells for shipping. No wastewater is generated from this process for producing paste separator material. All of the water added to form the paste mixture is incorporated in the finished cells, and the equipment used to blend the paste is not washed. Also, the floor in the paste preparation area is vacuum cleaned, eliminating floor wash water.

Two plants produce paste separator material for use in silver chloride-zinc cells. Flour, zinc chloride and ammonium chloride are used in formulating the separator paste. The cathode is inserted into an anode can containing separator paste; spacers and support pieces are added; and the can is sealed. The only source of wastewater discharge is paste tool cleaning. This waste stream estimated at less than 5 l/day was not sampled. The components of the paste, which does not contain mercury, are the only pollutants in the wastewater.

Pasted Paper (With Mercury) Separator Preparation - Production of pasted paper separators involves blending a paste-like material; applying it to the surface of paper; and oven drying the resultant pasted paper. The raw materials used to form the paste consist of starch, methanol, mercuric chloride, methocel, silica, and water.

The manufacture of pasted paper separator material containing mercury is specific to battery manufacturing and is included under battery manufacturing. When purchased the separator material is inserted directly into the zinc can, followed by cathode mix. Therefore, no wastewater is associated with separator application by these Leclanche cell manufacturers.

The only source of wastewater discharge during pasted paper manufacture is hand washing and washing of equipment used to handle the paste. This wastewater was sampled. The measured flows ranged from 0.11 to 0.17 l/kg of applied dry paste material (0.14 l/kg mean and 0.15 l/kg median). The analytical results for this waste stream are presented in Table V-57 (Page 316). Table V-58 (Page 317) presents the daily pollutant mass loadings of the paste equipment clean-up operation wastewater. Significant pollutants observed include zinc, manganese, mercury, TSS, and oil and grease.

Among these significant pollutants, zinc and manganese dioxide are not raw materials in paste formulation. They are presumed to derive from adjacent areas in which zinc chloride and manganese dioxide are handled.

The presence of TSS in significant concentrations results from washing equipment surfaces to remove process material accumulations. Oil and grease is also present in significant concentration due to the removal of equipment lubricants during the wash operation. There is considerable variability in pollutant concentrations during the three sampling days because of the nature of the hand wash and cleaning operations.

One plant which manufactures and sells mercury containing pasted paper separators (but does not make batteries) was visited. In-process controls and contract hauling are used to eliminate process wastewater discharge.

Pasted Paper (Without Mercury) Separator - Some of the Leclanche cell manufacturers use pre-pasted paper separator materials which does not have a mercury component. The wastewater resulting from manufacturing the paper separator material which does not contain mercury is not specific to the battery industry since the product has other industrial uses in addition to Leclanche cell manufacturing.

Equipment and Area Cleanup - Equipment and area cleanup (including handwash) wastewater in the Leclanche subcategory is that which cannot be associated solely with anode, cathode, or separator production. The operations generating this wastewater are:

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PLANT	OPERATION
A	Electrolyte preparation equipment wash
B	Cathode carrier wash
C	Hand washing
C	Miscellaneous equipment wash
D	Electrode preparation equipment wash
E	Electrolyte preparation equipment wash
F	Electrolyte preparation equipment wash

Out of the nineteen active Leclanche plants, thirteen reported no discharge of process wastewater: four of the 13 reported neither process water use nor wastewater discharge, while nine reported water use but no discharge. The six remaining plants listed above reported both water use and water discharge. Water use at the nine plants reporting use but no discharge is for electrolyte preparation.

Table V-59 (Page 318) indicates the best available information on equipment and area cleanup wastewater discharges for the nineteen Leclanche plants. The flow is normalized in terms of weight of finished product, and is expressed in liters discharged per kilogram of finished product.

Equipment and area cleanup wastewater samples were taken at Plants B and C. Pollutant concentrations from these sampled plants and also plant supplied data are included in Table V-60 (Page 319). Table V-61 (Page 320) presents pollutant mass loads expressed as milligrams discharged per kilogram of cells produced. Table V-62 presents statistics based on the values in Table V-60, and Table V-63 (Page 322) presents statistics based on the values in Table V-61.

Total Process Wastewater Characteristics - A statistical summary of total process wastewater characteristics from Leclanche subcategory plants is presented in Table V-64 (Page 323).

LITHIUM SUBCATEGORY

This subcategory encompasses the manufacture of batteries combining lithium anodes with a variety of depolarizer materials. Because lithium reacts vigorously with water, electrolytes used in these batteries are generally organic liquids or solids or solid inorganic salts which are fused during activation of thermal batteries. While manufacturing processes vary considerably among the different battery types included in this subcategory, they have in common limited use of process water and relatively low volumes of process wastewater.

Manufacturing Processes

The manufacture of batteries in this subcategory is illustrated in the generalized process diagram shown in Figure V-20 (Page 212). The manufacture of lithium anodes generally involves only mechanical forming of metallic lithium to the desired configuration and is not reported to involve process water use at any facility. Depolarizers used with the lithium anodes are frequently blended with or dissolved in the cell electrolyte and include iodine, iron disulfide, lead iodide-lead sulfide-lead (mixed), lithium perchlorate, sulfur dioxide, thionyl chloride and titanium disulfide. Preparation and handling of three of these depolarizers, iron disulfide, sulfur dioxide, and thionyl chloride, is reported to yield process wastewater. Cell assembly techniques differ with specific cell designs, but are universally accomplished without the use of process water or the generation of process wastewater. Usually, cell assembly is accomplished in special humidity controlled "dry" rooms. Thermal batteries manufactured in this subcategory include a heating component in addition to the anode, depolarizer, and electrolyte discussed above. The manufacture of one type of heating component, "heat paper", results in process wastewater as described previously in the calcium subcategory. One additional ancillary operation reported in this subcategory which produces process wastewater is the disposal of scrap lithium by reaction with water. The relationship between the process elements and discrete wastewater sources reported at battery facilities is illustrated in Figure V-21 (Page 213).

Anode Manufacture

All cells manufactured in this subcategory employ a lithium anode which is metallic lithium in the charged state. The anode is generally prepared from purchased metallic lithium sheet or foil by mechanical forming operations only, although one facility reported the preparation of a lithium alloy for use in high temperature batteries. In some cases the anode may also include a support structure of non-reactive metal such as aluminum screen. The use of pasted or powder anodes as observed in other subcategories is not reported, apparently because the high reactivity of lithium and relatively low current drains for which most lithium cells are designed do not necessitate maximized anode surface areas. No manufacturer in this subcategory reported process wastewater resulting from anode preparation.

Cathode Manufacture

Iodine Cathode Manufacture - The depolarizer for lithium iodine batteries is created by the mixture of iodine with an organic solid, poly-2-vinyl pyridine. This mixture is added to the cells in a molten state and, upon cooling, yields a conductive solid mass containing the reactive iodine. The electrolyte in these cells is solid lithium iodide which forms at the interface between the anode and depolarizer

after assembly of the cell. No process water is used in manufacturing these cathodes, and no process wastewater results.

Iron Disulfide Cathode Manufacture - Iron disulfide is used as a depolarizer in thermal batteries which use lithium anodes. Production of battery quality iron disulfide depolarizer may generate a process wastewater stream.

Lead Iodide Cathode Manufacture - This cathode is reported to be a mixture of lead iodide, lead sulfide and lead. Specific manufacturing processes employed were not identified, and points of process water use are uncertain although water use in fume scrubbers was indicated. (To be resolved during plant visits and follow-up).

Lithium Perchlorate Cathode Manufacture - Manufacture of this type of cathode was reported only on a small scale in sample quantities. Manufacturing process details were not supplied, but no process wastewater discharge from the production of this type of cathode was indicated.

Sulfur Dioxide Cathode Manufacture - The manufacture of cathodes for cells using sulfur dioxide as the depolarizer begins with the preparation of a porous carbon electrode structure, generally by pasting on a metallic grid. Binders such as teflon may be added to the carbon paste. The sulfur dioxide is mixed with an organic solvent (generally acetonitrile) and one or more inorganic salts such as lithium chloride or lithium bromide. The resultant liquid organic electrolyte-depolarizer mixture is subsequently added to the cells, and they are sealed. Wastewater produced in the manufacture of these cathodes results from wet scrubbers used primarily to control SO_2 emissions, and from wet clean-up in case of spills. Industry data indicates that spills are very infrequent.

Thionyl Chloride Cathode Manufacture - Manufacturing processes for the production of cells using thionyl chloride as the depolarizer are similar to those discussed above for sulfur dioxide depolarized cathodes except that the organic electrolyte acetonitrile is not used. The production of these cathodes also results in process wastewater from fume scrubbers and (potentially) from the clean-up of spills of process materials.

Titanium Disulfide Cathode Manufacture - Titanium disulfide cathodes are made by blending the active material (as a powder) with a binder and inserting the mixture in a metal can. Electrolyte, which is formed from dioxolane and sodium tetraphenyl boron, is added separately after insertion of the cell separator and anode. No process water use or wastewater discharge is reported from this process.

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Ancillary Operations

Heating Component Production

Heat Paper Production - Wastewater is generated by the manufacture of heat paper for use in thermal cells manufactured in this subcategory. The heat paper production process is identical to that previously discussed in the calcium subcategory.

Heat Pellet Production - No process water use or discharge is generated from this process which is used in the manufacture of thermal batteries. Heat pellet production is identical to that discussed under the calcium subcategory discussion.

Scrap Disposal. Lithium scrap is disposed at some sites by reacting it with water. Although no discharge of the resultant solution is reported at present, this scrap disposal process is a potential source of process wastewater.

Subcategory Data Summary

Seven plants reported the manufacture of a total of eight different types of batteries within this subcategory. These facilities range in production from less than 50 kg per year (100 lbs/yr) to 14 metric tons (15.5 tons) and in employment from 4 to 175. While plants differ significantly in products, manufacturing processes, production volume, and employment, all report little or no wastewater discharge and relatively few process wastewater sources. Consequently, existing wastewater treatment and available effluent monitoring data are limited.

Production - Because lithium battery technologies are rapidly changing, production patterns are also undergoing rapid change. Three of seven identified producers were not manufacturing in this subcategory during 1976 and submitted production data for more recent years. Consequently, it is not possible to compare plant production figures, on any single annual basis. Based on the submitted figures, one plant accounts for more than half of the total subcategory output. However, several facilities reported only prototype, sample, or start-up production with larger scale operations anticipated in the near future.

At present, lithium subcategory production is heavily concentrated in the northeastern U.S. with one facility in EPA Region I, two in Region III and three in Region II. The other producer was a small operation in Region IX.

Water Use and Wastewater Discharge - As previously indicated, water use and process wastewater discharge in this subcategory is quite

limited. Only three of seven plants in the subcategory reported process wastewater discharges. These ranged from 3.9 l/hr (1 gal/hr) to 150 l/hr (39 gal/hr). Process operations identified as sources of process wastewater discharge and reported production normalized wastewater flow rates for each are identified in Table V-65 (Page 324).

Wastewater Treatment Practices and Effluent Quality - Present wastewater treatment practices within this subcategory are limited to pH adjustment and settling at one facility and pH adjustment at another. Effluent monitoring data were submitted by only one facility. These data, already presented in the discussion of the calcium subcategory, characterized the wastewater discharge resulting from heat paper production.

MAGNESIUM SUBCATEGORY

The magnesium subcategory includes manufacturing operations producing cells combining magnesium anodes with a variety of depolarizer materials. Many of the cell types produced are reserve cells which are activated by electrolyte addition or by initiation of a chemical reaction to raise the cell temperature to operating levels. One type of cell, magnesium-carbon, presently accounts for over 85 percent of the total production in the subcategory. A number of different process operations in the subcategory are observed to yield process wastewater. These waste streams vary significantly in flow rates and chemical characteristics.

Manufacturing Process

The manufacture of magnesium anode batteries is illustrated in the generalized process flow diagram of Figure V-22 (Page 214). Anode manufacture generally involves mechanical forming and cutting of magnesium metal, and cleaning and chromating of the formed product. Cathodes are prepared by a variety of techniques including blending and pressing of powdered materials, and processes involving chemical treatment operations. Material used as a cell separator is chemically treated at one facility producing a process wastewater stream. Heating components (heat paper) are manufactured at one plant in the subcategory for assembly into magnesium anode thermal batteries. One facility reported testing assembled cells with a subsequent wastewater discharge. The relationship between the process elements and discrete wastewater sources reported at battery facilities is illustrated in Figure V-23 (Page 215).

Anode Manufacturing

Anodes used in this subcategory are primarily mechanically formed metallic magnesium, except for thermal cells where the anode is

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magnesium powder. In the case of magnesium-carbon cells, the anode may form the can in which the cell is assembled. In other cell types and in some magnesium-carbon cells, the anode is cut from magnesium sheet or foil. Magnesium anodes used in magnesium-carbon cells are generally cleaned and chromated before assembly into the cells. The chromate conversion coating on the magnesium anode serves to suppress parasitic reactions during storage and reduce self-discharge of these cells. These operations as well as the metal forming operations to produce magnesium cans may be performed on-site at the battery manufacturing plant or by a separate supplier.

The cleaning and chromating processes involve subsequent rinse operations which produce a wastewater discharge. These processes as well as the metal forming steps, however, are common mechanical operations. As a result, the wastewater effluents produced are not considered under battery manufacturing. No battery manufacturing process wastewater results from the production of these anodes.

Cathode Manufacturing

Carbon Cathode Manufacturing - The manufacture of cathodes for magnesium-carbon cells involves the separate preparation of a carbon current collector and of a depolarizer mix. The carbon current collector is formed by blending carbon with binder materials to produce a solid cathode structure. This may take the form of a solid rod to be inserted in the center of a formed magnesium can or of a carbon cup within the cell is assembled.

The depolarizer for these cells, manganese dioxide, is blended with carbon and other inorganic salts such as barium and lithium chromate to enhance conductivity through the depolarizer mix. Magnesium perchlorate electrolyte may also be added to this mixture before assembly into the cell. No process wastewater discharge was reported from the manufacture of carbon cathodes or depolarizer material by any plant in the subcategory.

Copper Chloride Cathode Manufacturing - The production of copper chloride cathodes for use in reserve cells is reported to proceed by forming the powdered material into pellets which are subsequently inserted into the cell assembly. No process wastewater results.

Copper Iodide Cathode Manufacturing - The manufacture of this cathode type involves mixing cuprous iodide, sulfur, and carbon and sintering the mixture. The sintered material is subsequently ground and pressed on a supporting copper grid to form the cathode which is dipped in an aqueous alcohol solution prior to insertion in the battery. Only noncontact cooling water is used in this process, and no process wastewater results.

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Lead Chloride Cathode Manufacturing - Lead chloride cathodes are reported to be produced by pressing lead chloride on a copper screen. No process wastewater is generated.

M-Dinitrobenzene Cathode Manufacturing - Cathodes in which this material serves as the depolarizer are produced by mixing m-dinitrobenzene with carbon or graphite, ammonium thiocyanate, and glass fiber. The mixture is subesquently molded or pasted to produce a thin sheet which is in contact with a flat stainless steel current collector in the assembled cell. No process wastewater is reported to result.

Silver Chloride Cathode Manufacturing - Three different processes are reported for the production of silver chloride cathodes for use in reserve cells. Two of these involve chemical processing and result in process wastewater streams, while the third is strictly a physical process involving no water use and no process wastewater discharge.

Silver chloride cathodes are produced by one manufacturer by forming silver chloride powder into pellets which are subsequently assembled into reserve cells. The manufacturing process is reported to be similar to that for the production of copper chloride cathodes.

In another process, silver chloride is calendered into strips and punched. The resultant material is then treated with photo developers to reduce the surface to metallic-silver. The cathode material is then rinsed, yielding a process wastewater stream, and subsequently sent to cell assembly.

Alternatively, silver is electrolytically oxidized in hydrochloric acid to produce silver chloride. The product of this operation is subsequently rinsed, dried, and used in assembling cells. Process wastewater results from rinsing the electrolytic silver chloride.

Vanadium Pentoxide Cathode Manufacturing - Vanadium pentoxide, used as the depolarizer in magnesium anode thermal batteries, is blended with electrolyte (lithium chloride and potassium chloride) and kaolin as a dry powder and pressed to form pellets which are used in cell assembly. No water is used directly in this process, but wastewater is discharged from fume scrubbers on dehumidifiers used to dry manufacturing areas.

Cell Assembly

Details of the cell assembly process vary significantly among the different types of cells manufactured in this subcategory. None of the cell assembly processes, however, are reported to generate process wastewater.

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For magnesium carbon cells, the separator, depolarizer mix, and cathode are inserted in the magnesium anode can, electrolyte is added, and assembly is completed by sealing and adding contacts and a steel outer case. Alternatively, magnesium carbon cells are assembled by insertion of the anode in the annular carbon cathode cup and placement of cathode mix in the spaces between anode and cathode. After this, electrolyte is added, the cell is sealed, and contacts and a steel outer case are added to complete assembly. The electrolyte used is an aqueous solution of magnesium perchlorate.

In assembly of ammonia activated magnesium reserve cells, the ammonia which forms the electrolyte is placed in a sealed reservoir within the battery assembly from which it is pumped into the cells upon activation of the battery. Solid electrolyte is incorporated in pellets containing the depolarizer in magnesium anode thermal batteries. In seawater activated cells, the saline seawater itself serves as the electrolyte, and none is added during assembly of the cells.

Ancillary Operations

Heating Component Manufacture - Magnesium anode thermal batteries are activated by heat generated in a chemically reactive element (heat paper) incorporated within the cell structure. The production of this cell component produces process wastewater as previously described for the calcium subcategory.

Separator Processing - One manufacturer reported the use of glass beads as the separator in magnesium reserve cells. These glass beads are reportedly etched using hydrofluoric acid and ammonium fluoride as a part of the manufacturing process. A subsequent rinse results in a process wastewater discharge. This process is not presently active, although resumption of production is possible.

Cell Test Operation - After assembly, quality control tests on magnesium reserve cells may include activation to verify satisfactory performance. Water used in this operation (destructive testing) was reported to constitute a source of process wastewater by one manufacturer of magnesium reserve cells.

Floor Wash Operation - The removal of contaminants from production area floors is frequently required for hygiene and safety. This may be accomplished in many cases by dry techniques such as sweeping and vacuuming but may also require the use of water in some instances. One plant in this subcategory reported floor washing and indicated a resultant process wastewater discharge.

Subcategory Data Summary

Production - Total 1976 annual production of batteries in this subcategory as reported in dcp's was 1220 metric tons (1340 tons). Over 85 percent of this total was produced as magnesium-carbon batteries. Thermal batteries and ammonia activated reserve batteries together accounted for less than 1 percent of the total. The remainder comprises a variety of magnesium reserve cells generally intended for seawater activation.

Eight facilities reported production of batteries in this subcategory. Two of the eight facilities account for 84 percent of the total production. These two plants manufacture magnesium-carbon batteries as does the third largest facility. None of these plants reported the production of any battery manufacturing wastewater.

Six of the eight facilities manufacturing magnesium anode batteries report production in other battery manufacturing subcategories as well. Magnesium-carbon battery production is co-located with Leclanche subcategory production in two of three instances. This association is logical since cathode materials and cell assembly techniques are quite similar for these cell types. Other subcategories represented on-site with magnesium subcategory production include the cadmium subcategory, lead subcategory, lithium subcategory, and zinc subcategory. In most cases, magnesium subcategory production accounts for less than 30 percent of the total weight of batteries produced at the facility. Because of the limited use of water and wastewater discharge associated with magnesium subcategory operations, combined wastewater discharge and treatment are rare despite the high incidence of common-site production. Wastewater from magnesium subcategory production is combined with wastes from other subcategories at only one facility. Since no production operations are common at that site, segregation of wastes at that facility is feasible.

Geographically, producers in this subcategory are scattered. One plant is located in each of U.S. EPA Regions I, III, VI and VIII, two in Region IV, and two in Region V. No two facilities are located in the same state.

Water Use and Wastewater Discharge - Process water use varies considerably among manufacturers in this subcategory. As shown in the preceeding manufacturing process discussion, most process operations are accomplished without the use of process water. In addition, many of the cell types produced either use non-aqueous electrolytes or are shipped without electrolyte.

Process operations which result in battery manufacturing wastewater are reported at four of the eight plants in the subcategory. Pro-

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duction normalized wastewater flows from each of these process operations are presented in Table V-66 (Page 325). Total process wastewater flow rates are reported to range from 0 to 5200 l/hr (1370 gal/hr) with an average of 670 l/hr (180 gal/hr). Wastewater discharges from plants in this subcategory are equally split between direct and indirect discharge. Total process wastewater discharge from magnesium subcategory processes at individual plants is presented in Table V-67 (Page 326).

Wastewater Treatment and Effluent Quality - Present wastewater treatment practice within this subcategory is limited. Treatment practices at most facilities are limited to pH adjustment and removal of suspended solids. One plant reported the use of settling tanks followed by filtration for this purpose. No effluent analyses specifically characterizing treated wastewater from this subcategory were supplied in dcp's.

ZINC SUBCATEGORY

Batteries manufactured in this subcategory all employ a zinc anode which is amalgamated to reduce anode corrosion and self-discharge of the cell. They also have in common the use of an alkaline aqueous electrolyte which is primarily composed of potassium or sodium hydroxide. The zinc anodes employed, however, vary considerably in physical configuration and in production techniques depending upon the desired operational characteristics of the cells produced. This subcategory encompasses batteries manufactured for a variety of uses with different performance characteristics and physical dimensions. Six different depolarizers are used in these cells, and cathodes for cells using some of these depolarizers may be produced by several different techniques.

Process water is used in many of the operations performed in the manufacture of batteries in this subcategory, and flow rates are sometimes high. Process wastewater is discharged from most plants and characteristically results from a number of different manufacturing processes. Because of the large number of different wastewater producing operations in the subcategory and the variety of patterns in which they are combined at individual plants, plant wastewater discharges are observed to vary widely in wastewater flow rates and in chemical characteristics. Wastewater treatment practices and effluent quality are also observed to vary significantly within the subcategory. However, the flow rates and chemical characteristics of wastewater from specific process operations performed at different sites are generally observed to correspond. Observed differences can usually be accounted for by observed variations in plant water conservation practices.

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Manufacturing Process

The manufacture of zinc subcategory batteries may be represented by the generalized process flow diagram presented in Figure V-24 (Page 216). The anode and cathode variations observed in this subcategory together with ancillary operations which generate process wastewater formed the basis for analysis of process wastewater generation as illustrated in Figure V-25 (Page 217). As shown in the figure, several distinct waste streams frequently result from a single process operation or function.

Not all operations shown on this diagram are performed at each plant in the subcategory, and in some cases, the order in which they are performed may vary, but in most cases the overall sequence of process operations is similar. Few plants generate process wastewater from all of the process operations indicated on the diagram. At most facilities some of these production steps are accomplished without generating a waste stream. The specific operations performed by these "dry" techniques varies from site to site and each of the indicated wastewater sources is observed at one or more plants in the subcategory.

Anode Operations

Amalgamation - Zinc anodes used in these cells commonly corrode by reactions with the cell electrolyte in which hydrogen gas is evolved. Hydrogen overvoltage and thus anode corrosion in the cell is suppressed by zinc anode amalgamation. This reduction in the rate of anode corrosion is essential to the achievement of acceptable battery life, and anode amalgamation is universal in this subcategory. Because many of the cells produced are designed for high discharge rates, powdered zinc and porous structures are used in anodes to maximize electrode surface area. Mercury requirements for amalgamation are consequently increased, and mercury consumption in amalgamating anodes in this subcategory is typically 0.05 kg per kg of zinc as compared to 0.00035 kg per kg of zinc in the Leclanche subcategory. This increase in mercury requirements influences the amalgamation techniques which may be employed as well as the severity of mercury pollutant discharge problems encountered.

Amalgamation is presently accomplished by six distinct techniques depending in part on the anode configuration produced and in part on the preference of the manufacturer. Present practice includes amalgamation by inclusion of mercury (alloying with zinc) during casting of anode material; amalgamation by mixing zinc and mercury salts or mercury in an aqueous solution from which the product is removed (wet amalgamation) with subsequent rinsing of product; mixing zinc, mercury, electrolyte and a gelling agent to form amalgam gel (gelled amalgam); blending mercury and dry zinc powder (dry

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amalgamation); mixing zinc and mercuric oxides prior to pressing or pasting the material on a supporting grid; and amalgamation by immersing the anode in a solution of mercury salts. The processes of wet amalgamation of zinc powder, production of gelled amalgam, and anode immersion cause mercury to be present in plant wastewater directly through wastewater discharges resulting from these operations. Other amalgamation processes may result in the presence of mercury in the plant wastewater streams as a result of subsequent process water contact with the amalgamated anode materials.

Amalgamation by incorporation of mercury in the zinc casting is employed in the production of cast anodes for use in air-depolarized cells. Because of their relatively low surface area per unit weight, these cast anodes are not suitable for use in cells designed for high discharge rates. This amalgamation process does not result in the generation of any process wastewater.

The process of wet amalgamation of zinc powder is used by facilities producing alkaline manganese cells and a variety of button cells with mercury and silver cathodes. In this process, zinc and mercury are mixed in an aqueous solution which generally contains either ammonium chloride or acetic acid to enhance the efficiency of amalgamation. Subsequently, the solution is drained away and the amalgam product is rinsed, usually in several batch stages. A final alcohol rinse is frequently used to promote drying of the product. Binders such as carboxymethyl cellulose (CMC) are commonly added to the dry amalgamated zinc powder which aid in compaction of the anode in the cells. Wastewater from this process results from discharge of the spent amalgamation solution and from subsequent rinses as well as from washing of amalgamation equipment and floor areas. The final alcohol rinse is generally retained and reused until ultimately contractor re-moved.

The gelled amalgam process results in production of moist anode gel in a single operation. Zinc powder, mercury and electrolyte are combined with a gelling agent such as carboxymethyl cellulose and mixed to achieve the desired anode mix characteristics. Mixing equipment used in this operation and process floor areas are washed with water to minimize mercury exposure to workers and to limit equipment corrosion by the electrolyte added to the gel.

In the dry amalgamation process zinc powder and metallic mercury are mixed for an extended period of time to achieve amalgamation. The resultant material may subsequently be mixed with a binder such as CMC and moistened with electrolyte to aid in compaction of the anodes in the cells. Amalgamation equipment used for this process may generally be cleaned by dry techniques eliminating all process water use and wastewater discharge. Discussions with industry personnel have

indicated that this process is less costly than wet amalgamation and has resulted in satisfactory anode performance.

Amalgamation of anodes prepared from zinc oxide powder is accomplished by mixing mercuric oxide powder with the zinc oxide. An amalgam is produced upon subsequent reduction of the zinc oxide to zinc during electrode formation. This amalgamation process does not produce any direct wastewater discharge but results in the presence of mercury in wastewater resulting from pasting or pressing electrodes and from subsequent formation steps unless these are accomplished within the battery case.

Electrodeposited zinc anodes are amalgamated by immersion in a mercuric chloride solution. In present practice, amalgamation is sometimes followed by a rinsing step. The amalgamation solution is periodically dumped generating process wastewater containing extremely high concentrations of mercury and zinc.

Amalgamation by inclusion of mercury in the cell separator or electrolyte as observed in the manufacture of Leclanche subcategory batteries is not practiced by any manufacturer in the zinc subcategory. This may be attributed to the higher surface areas of electrodes used in these cells (and correspondingly higher mercury requirements) as well as the fact that many cells are designed to contain minimal electrolyte. These conditions may make it impractical to include sufficient mercury in either the separator or electrolyte. Further, the lack of mixing involved in this method of addition could make the rate of mercury transport through the porous anode volume (and hence of amalgamation) unacceptably low.

Anode Preparation - The nature and extent of anode preparation operations varies considerably. Cast anodes may be used directly or subjected only to physical cutting or machining. As previously indicated, amalgamated zinc powder may be mixed with binders and electrolyte and is then generally simply pressed in place during assembly with no further preparation required. In the manufacture of anodes from zinc oxide, the zinc oxide is mixed with mercuric oxide and a binding agent such as polyvinylalcohol (PVA) and then pasted or pressed onto supporting metal grids. These electrodes may be subsequently formed by electrolytic reduction of zinc oxide to zinc and rinsed producing a process wastewater discharge. The preparation of electrodeposited anodes involves electrolytic deposition of zinc on a metallic grid and subsequent rinsing of the resultant anode. In this case, anode preparation precedes amalgamation.

Cathode Operations

Depolarizer Material Preparation - Depolarizers used in this subcategory are primarily metal oxides which are purchased from

manufacturers of inorganic chemicals. In some cases, however, depolarizer material is chemically prepared on-site because special characteristics are required for battery manufacture. Commercially available depolarizer materials may also be prepared on site at battery plants in processes equivalent to those used in inorganic chemicals manufacturing operations which are not considered part of battery manufacturing.

Mercuric oxide, which serves as the depolarizer in mercury cells, is commonly purchased by battery manufacturers. One plant, however, produces this material on-site from metallic mercury in a chemical process which produces process wastewater containing considerable quantities of mercury. This process is located in a separate building from the actual battery manufacturing operations and its wastewater discharge is treated in a separate system. Since the mercuric oxide product is available commercially, this process is considered inorganic chemicals manufacture and its effluent is not considered under battery manufacturing.

Silver peroxide, used as the depolarizer in batteries manufactured in this subcategory, is produced on-site. The production process includes wet oxidation of monovalent silver oxide by either of two alternative chemical processes and subsequent rinsing of the product. Because this operation is unique to battery manufacturing operations, the resultant wastewater discharge is addressed as a battery manufacturing effluent. Silver powder is also produced on site at battery manufacturing plants for use in cathode manufacture. It is produced by electrolytic deposition, mechanical removal from the substrate, and rinsing. Rinsing the powder produces a wastewater discharge which is regulated under the zinc subcategory. Silver peroxide and silver powder production are addressed as separate ancillary operations in this subcategory.

Cathode Preparation - Variations in cathode preparation techniques are similar to those described for anode manufacture except that in addition to differences in configuration, differences in depolarizer material are also significant in this case. Ten distinct cathode manufacturing processes are observed in this subcategory producing the following types of cathodes:

1) Porous Carbon
2) Manganese Dioxide
3) Mercuric Oxide
4) Mercuric Oxide-Cadmium Oxide
5) Pressed Silver Powder
6) Pressed and Electrolytically Oxidized Silver
7) Pressed Silver Oxide Powder
8) Pressed, Reduced and Electrolytically Oxidized
   Silver Oxide Powder

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9) Pasted and Pressed Silver Peroxide Powder
10) Impregnated Nickel

Porous carbon cathodes are used in air depolarized cells and are produced by blending carbon, manganese dioxide and water and pressing and drying the mixture to produce an agglomerated cathode structure or "agglo" which serves a current collector for the cathode reaction and as a porous medium to carry atmospheric oxygen to the electrolyte. Control of the porosity and surface characteristics of the agglo is essential since the cathode must permit free flow of oxygen through the pores, but not become flooded with the electrolyte in which it is immersed. Flooding of the agglo would reduce the surface area over which reaction with oxygen could occur to such an extent that practical cell operation could not occur. The manufacture of this cathode type is not reported to result in process wastewater.

Manganese dioxide serves as the depolarizer in alkaline manganese cells. Manganese dioxide cathodes are prepared by blending manganese dioxide with carbon and binders such as cement (and in some cases sufficient electrolyte to wet the mixture). The cathode is formed by pressing the mixture into a steel cell container which serves as current collector and support. The carbon in the cathode mix serves to provide conductivity through the cathode since manganese dioxide itself conducts poorly. Although water is used in wetting the cathode mix, no process wastewater discharge associated with production of this type of cathode is reported.

The manufacture of mercuric oxide cathodes reported by five facilities (production at one facility has ceased since submittal of dcp), is accomplished in a process similar to that described above for manganese dioxide cathodes. Mercuric oxide as a dry powder is blended with graphite and sometimes with manganese dioxide, pressed into shape, and inserted in steel cell containers. No process wastewater is generated.

The mercuric oxide-cadmium oxide cathode is closely related to the mercuric oxide cathode and is manufactured by the same process except that cadmium oxide is included in the depolarizer mix. The function of the cadmium oxide is to provide continued cell operation at a reduced voltage for an interval after the mercuric oxide in the cathode is depleted. This characteristic is exploited in devices such as battery powdered smoke detectors to provide a warning of impending battery failure. Production of this type of cathode was reported by one plant in the subcategory. No process wastewater results.

The manufacture of pressed silver powder cathodes begins with the production of silver powder which is prepared on-site by electrodeposition. The resultant powder is pressed on the surface of a silver screen or other support and sintered to achieve mechanical

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integrity. These electrodes may then be assembled with unformed (oxidized) zinc anodes and the resultant batteries charged prior to use. The only process wastewater resulting from the manufacture of these cathodes is associated with the production of silver powder which is addressed as a separate ancillary operation.

Cathodes may also be produced from silver powder as described above and subsequently formed prior to cell assembly. Silver powder used in producing cathodes of this type may be produced on-site or purchased. The formation process is accomplished by electrolysis in a potassium hydroxide solution and generally involves several charge-discharge cycles with the final state of the electrode being the charged silver oxide state. Formation of the cathodes is followed by rinsing which results in the generation of process wastewater.

The preparation of cathodes using silver oxide powder proceeds simply by blending solid constituents and pressing them to produce cathode pellets for use in silver oxide-zinc button cells. Depending upon desired cell characteristics, manganese dioxide, magnesium oxide, and mercuric oxide may be added to change the cell voltage and the shape of the discharge curve. Manganese dioxide provides a period of gradual voltage decline after exhaustion of the silver oxide allowing cells used in devices such as hearing aids to "fail gracefully" and giving the owner time to replace them. Graphite is added to provide additional conductivity within the cathode while the silver is in the charged (oxide) state, and binders are typically added to improve mechanical integrity.

Cathodes may also be produced by applying a paste of silver oxide powder and water to a supporting silver grid. This material is then thermally reduced to silver metal and sintered. Afterwards, the sintered material is charged to the oxide state by electrolysis in potassium hydroxide solution and rinsed. Rinse water and spent formation solutions constitute sources of process wastewater.

The production of silver peroxide cathodes begins with the oxidation of silver oxide to produce silver peroxide. Subsequently, the resultant material may be processed in two ways depending upon cell configuration. Silver peroxide may be mixed as a slurry and applied to a supporting silver grid to create the cathode structure or it may be blended with other materials and formed into pellets for use in button cells. In the first case, wastewater results from washing paste mixing and application equipment. In the latter case, subsequent chemical treatment of the pellet cathodes results in the generation of process wastewater discharges. The production of silver peroxide is addressed as a separate ancillary operation in this subcategory.

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Nickel hydroxide cathodes used in this subcategory are prepared by sintering, impregnation and formation processes as described for the cadmium subcategory.

Ancillary Operations

Electrolyte Preparation - The electrolytes used in cells in this subcategory are primarily aqueous solutions of either potassium or sodium hydroxide but may in some cases contain zinc oxide as well. In general, they are added to the batteries in solution form during cell assembly and must first be prepared from purchased solid constituents. The preparation of these electrolyte solutions sometimes results in the generation of some process wastewater, particularly where different cell types requiring a variety of electrolyte compositions are produced, and electrolyte mixing equipment is rinsed or washed between batches of electrolyte.

Cell Assembly - The specific operations involved in cell assembly in this subcategory are as varied as the physical configurations of the cells produced. These include button cells, cylindrical cells with pressed cathodes and powdered zinc anodes, and rectangular cells with stacked flat electrodes. In general terms assembly of all of these cells involves placement of the cell separator(s) between the anode(s) and cathode(s), insertion of the electrodes and separator in the cell case, addition of electrolyte, sealing the cell, and application of cell contacts involving both intercell connections and outer battery housing as required. Process wastewater is not produced directly from cell assembly operations although some facilities report spillage of small volumes of electrolyte which is collected and either reused or disposed.

Cell separators used in this subcategory vary widely in materials and configuration. Materials used include nonwoven cellulose, paper, cellophane, and nylon. However, manufacture or handling of separators is not reported as a source of process wastewater.

Cell Washing - Many of the cells produced in this subcategory are washed prior to assembly or shipment. These cell wash operations serve to remove spilled electrolyte, oils and greases, and general soil from the cell case and minimize the probability of corrosion of the battery case and contacts or of devices into which the battery is placed. As described in more detail in connection with process wastewater characteristics, cell washing procedures vary significantly among plants and frequently involve multiple cleaning steps using different process chemicals. Both organic and inorganic cleaning solutions are used, but most cell cleaning processes include one or more water rinses resulting in wastewater discharge.

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Reject Cell Handling - Because of the high energy content of cells produced in this subcategory, cells rejected for defects during assembly could pose a fire or explosion hazard if shorted out during handling for disposal. For this reason, they are frequently placed in containers of water to provide a relatively high resistance short circuit and dissipate the cells energy safely. The water in these containers is exposed to all cell constituents for an extended period of time and is thus potentially contaminated with all battery component materials. However, the total volume of this wastewater is very small.

Employee Wash-up - Since mercury, zinc, cadmium, and other materials used in manufacturing batteries are toxic, washing of the hands and persons of workers who contact these materials is frequently required as a part of industrial hygiene procedures. Wastewater from these washing procedures contains process materials and is thus deemed battery manufacturing process wastewater.

Equipment Wash - The equipment used in manufacturing batteries may become contaminated with spilled electrolyte or electrode materials and require washing as a part of maintenance procedures. Four plants in the subcategory reported process wastewater from such equipment washing procedures.

Floor Wash - Production area floors require cleaning as a matter of industrial safety and hygiene. This may be accomplished in many cases by dry techniques such as sweeping and vacuuming, but three manufacturers in this subcategory reported floor washing operations with a resultant wastewater discharge.

Silver Etch - Silver foil is prepared for use in electrode manufacture by etching with nitric acid and subsequently rinsing the etched foil. Wastewater from this process constitutes another battery manufacturing waste stream requiring consideration.

Silver Peroxide Production - Silver peroxide for use in cathode manufacture is produced on-site at battery manufacturing plants by chemical oxidation of purchased silver oxide. Process wastewater discharges result both from spent process solutions and from water used in rinsing the silver peroxide product.

Silver Powder Production - The production of silver powder for use in battery cathodes by electrodepositon and mechanical removal from the substrate, can be produced for both zinc anode batteries and cadmium anode batteries as discussed under the cadmium subcategory. Wastewater is generated in rinsing the product.

Process Integration - The different process operations discussed above may in principle be combined in many ways for the manufacture of

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batteries. Table V-68 (Page 327) presents the combination of anode and cathode manufacturing processes observed in the subcategory at the present time. The extent of practice of the ancillary process operations discussed above is also indicated in the table. Of twenty-six distinct process operations or functions identified in the subcategory, seventeen are reported to result in process wastewater discharges. All of these discharge sources were represented in sampling at zinc subcategory plants.

Subcategory Data Summary

Five battery product types: alkaline manganese, mercury-zinc, silver oxide-zinc, nickel-zinc and carbon-zinc-air, are manufactured within this subcategory. In addition, silver oxide-zinc cells are produced using two different oxides of silver, silver oxide (monovalent) and silver peroxide. The silver peroxide yields a higher cell voltage and greater energy density. Plants in the subcategory vary widely in production volume, process wastewater generation, and manufacturing processes. Many produce more than one type of cell. Wastewater treatment practices and effluent quality are highly variable.

Production - Annual production in the subcategory totaled 22,300 metric tons (24,500 tons) broken down among battery product types as shown below:

Battery Type	No. of Producing Plants	Estimated Annual Production Metric Tons	Tons
Alkaline Manganese	8	17800	19600
Carbon-zinc-air	2	2010	2210
Silver oxide-zinc	9	1240	1360
Mercury-zinc	5	1230	1350
Nickel-zinc	1	0.23	0.25

Water Use and Wastewater Discharge - Wastewater discharge from zinc subcategory manufacturing operations as shown in Table V-69 (Page 329) varies between 0 and 26,000 l/hr (7,000 gal/hr). This variation may be understood on the basis of the variations among these plants in the mix of production operations employed, and the observed variability in water conservation practices in the subcategory. The impact of variations in manufacturing process is indicated in the data presented in Table V-70 (Page 330) which presents normalized wastewater discharge flows from both visit and dcp data, for each major process operation in this subcategory.

Wastewater Treatment and Effluent Characteristics - The plants in this subcategory reported the practice of numerous wastewater treatment technologies including pH adjustment, sulfide precipitation, carbon

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adsorption, amalgamation, sedimentation, and filtration. Several indicated the recovery of some process materials from wastewater streams. The effectiveness of these treatment techniques varies widely as indicated in the effluent data presented in Table V-71 (Page 331). In addition to the wastewater treatment systems reported in dcp's, a complete system combining in-process controls with ion exchange and wastewater recycle has recently been installed which will ultimately eliminate the discharge of wastewater effluent from one plant. Process changes at another plant have also eliminated process wastewater discharge since the data presented in the dcp were developed.

Specific Process Water Uses and Wastewater Characteristics

Anode Operations

Zinc Cast or Fabricated Anode - Anodes in this group are produced by casting or by stamping or forming of sheet zinc. In producing cast anodes, zinc and mercury are alloyed, and the mixture is cast to produce an amalgamated anode.

Two plants in the data survey reported using cast anodes for carbon-zinc-air cell manufacture. No process wastewater is generated in producing anodes by this procedure.

Zinc Powder - Wet Amalgamated Anode - The amalgamation process is conducted to reduce the corrosion of the zinc anode thereby increasing the cell shelf life. Anode material in this group is produced by amalgamation in aqueous solutions and subsequently rinsed. This process is consequently termed a wet amalgamation process. Wastewater discharges also result from both floor area and equipment clean-up operations occurring in conjunction with the amalgamation processes.

Six plants in the data base reported using wet amalgamated powdered zinc processes for anode formulation. Two plants have discontinued these operations. The amalgamation process starts with mixing zinc and mercury in an aqueous solution contained in a large blending tank. Some plants use an ammonium chloride solution whereas other plants mix zinc and mercury powders in an acetic acid solution. For both of these processes, the aqueous solutions used to amalgamate the zinc and mercury are drained, and the resulting product is rinsed. Both the process solution and the rinse wastewater are discharged. After sufficient rinsing, the moist amalgam is next rinsed in alcohol, and the excess alcohol is decanted from the product. The amalgam is removed from the tank and dried to a powdered form prior to adding binding agents which aid in compacting the anode material into the steel cans. Finally, cleaning procedures are conducted to remove impurities from the tank and other equipment in preparation for processing the next batch of amalgam material. The water used to

clean the equipment and floor area is also discharged. Figure V-26 is a schematic diagram of the zinc powder-wet amalgamation process. When the dried amalgamated product is found to be unacceptable for use in assembling batteries, it may be returned to the amalgamation area for reprocessing and further rinsing.

In summary, there are four sources of wastewater from the wet amalgamation process: (1) spent aqueous solution discharge; (2) amalgam rinses; (3) reprocess amalgam rinses; and (4) floor area and equipment wash discharge. The discharge from amalgamation (total of above four streams) ranges from 1.4 to 10900.8 liters per day at the seven plants which reported using the wet amalgamation process (2890.2 l/day mean and 1211.2 l/day median). The production normalized discharge from both dcp and visit data ranges from 0.69 to 10.09 l/kg (3.8 l/kg mean and 2.2 l/kg median).

The wastewaters from wet amalgamation processes at two plants were sampled. The normalized discharge flow during sampling ranges from 1.88 to 6.82 l/kg (4.2 l/kg mean and 3.8 l/kg median). The entire amalgamation process wastewater was sampled at both facilities. Wastewater from amalgam preparation and equipment cleaning was combined. Another waste stream at one plant is associated with reprocessing amalgamated material. During the sampling visit amalgam that had been previously stored was being reprocessed intermittently throughout the three sample days because the oxidation level was unacceptable for further processing. This material is first submerged in acetic acid to alleviate the oxidation problem and the subsequent processing is the same for "virgin" amalgam batches; however, the mercury concentration in the wastewater of the "virgin" amalgam process will be substantially greater than that of the reprocessed amalgam since no additional mercury is mixed into the latter material.

After completion of the amalgamation process, the amalgamated powdered zinc is either compacted or mixed with gelling materials to form semi-rigid anodes. One plant reported combining the amalgam with an unspecified gelling agent for the manufacture of button cells. No further specifics on this amalgamation process were provided. Three of the four remaining plants report adding a binding agent, carboxymethylcellulose, to the amalgam powder prior to compacting the resulting material into steel cans. The remaining plant did not specify the binding agent in either the raw material listing or process diagram.

Table V-72 (Page 332) presents the daily analysis results in units of mg/l for both sampled amalgamation processes. Higher zinc concentrations observed in wastewater from one plant result from the malfunctioning of the amalgam mixer. Each load of amalgam did not completely empty out of the tank which required manually scraping the residue from the mixer and washing the remaining material from the

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tank by using a hose. This cleaning procedure increases the volume of water used in the amalgamation process and contributes to the zinc concentrations of the wastewater. Mercury was detected in all the amalgamation samples, and was measured at relatively high concentrations in samples at Plant B.

Table V-73 (Page 333.) presents the pollutant mass loading in the amalgamation samples taken daily at both Plants B and A. The range, mean, and median values in units of mg/l and mg/kg are presented in Tables V-74 and V-75 (Pages 334 and 335.), respectively.

Gelled Amalgam Anode - The production of gelled amalgam as illustrated in Figure V-27 (Page 220) begins with the combination of zinc and mercury powder in the appropriate proportions and the addition of potassium hydroxide solution to this mixture. The gelling agent, which is either carboxymethylcellulose or carboxypolymethylene, is blended in the amalgam mixture to achieve the appropriate gel characteristics. No wastewater discharge is directly associated with processing the gelled amalgam; however, both equipment and floor area are washed to remove impurities resulting from the amalgam processing. These maintenance procedures result in wastewater discharges.

Wastewaters from two plants (B and A) were sampled. Table V-76 (Page 336) presents the analysis results of these waste streams. The discharge flows on a daily basis range from 0.21 to 1.67 l/kg (0.69 l/kg mean and 0.48 l/kg median). The discharge flows measured at Plant B include the combined wastewater from both equipment and floor areas wash operations whereas the flow measurements at Plant A involve wastewater from floor washing only.

At Plant A, the water used to wash the amalgamation equipment is recirculated and dumped only once every six months. As a result, wastewater from this source amounts to approximately 0.001 l/kg, a negligible contribution to the total discharge volume.

All of the waste streams from amalgamation at these sites were sampled including the recirculating blender wash water at Plant A even though this water was scheduled for dumping one and a half months after the sampling visit was completed. The significant pollutants in these alkaline waste streams include TSS, mercury, and zinc which result from the removal of residual amalgam in the cleaning of utensils and equipment. In addition, spillage resulting from the bulk handling of raw materials for conducting the amalgamation process are removed during floor washing.

Zinc concentrations in amalgamation wastewater on the first sampling day at Plant B could not be calculated. Pollutant concentrations in this waste stream were not measured directly but were determined by mass balance using two wastewater samples representing wastewater

resulting from scrap cell deactivation and the mixed scrap cell deactivation and amalgamation wastewater. On the first day extremely high zinc concentrations in the scrap cell deactivation wastewater prevented meaningful determination of zinc concentrations in the amalgamation waste stream.

Another parameter that is present in significant concentrations in the anode room floor wash samples taken at Plant A is arsenic. The source of this pollutant is unknown although it may be a trace contaminant of the zinc used in the amalgamation process. The waste streams generated from washing both the amalgamation equipment and floor areas are highly alkaline resulting from the potassium hydroxide addition in gelled amalgam formulation and inclusion of utensil wash water from electrolyte preparation.

Table V-77 (Page 337) shows the daily pollutant mass loadings in units of mg/kg for both clean-up processes. Statistical analysis of these data are presented in Tables V-78 and V-79 (Pages 338 and 339) for both mg/l and mg/kg analysis results, respectively.

Three plants produce gelled amalgam. The resultant wastewater discharges range from 0.25 to 1.13 l/kg with a mean of 0.69 l/kg.

Dry Amalgamated Zinc Powder Anodes - The production of dry amalgamated powder proceeds simply by mixing mercury metal and zinc powder for an extended period of time. To control mercury vapor exposure of production workers, the mixing is commonly performed in an enclosed vented area separate from the material preparation areas. This process is truly dry and involves no process wastewater discharge. This process element also includes the production from zinc powder amalgamated off-site.

Two plants obtain amalgam produced off-site and one produces dry, amalgamated powder.

Zinc Oxide Powder - Pasted or Pressed Anodes - The manufacture of these anodes involves the preparation of a slurry consisting of zinc oxide and mercuric oxide. The mixture is then layered onto a grid. The resultant product is allowed to dry, and finally the dried material is compressed to eliminate irregularities such as jagged edges. The anode plaques are assembled with cathode plaques to manufacture batteries which are shipped unformed and later formed by the customer. Since the formation operation is not conducted on-site, there is no wastewater associated with anode formation. No other sources of wastewater associated with the production of this anode type were reported. Only one plant reported manufacturing slurry pasted anodes which are assembled with uncharged cathodes to produce cells to be later charged by the customer.

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Zinc Oxide Powder - Pasted or Pressed, Reduced Anodes - The production of anodes in this group involves mixing zinc oxide and mercuric oxide in either a slurry or dry powder form and applying the mixture onto grids. The pasted or pressed product is electrochemically formed in potassium hydroxide solution to convert zinc oxide to the zinc state and reduce mercuric oxide to mercury to amalgamate with the active zinc. After completion of formation, the anode material is rinsed to remove residual caustic.

The pressed powder technique for zinc anode formulation as illustrated in Figure V-28 (Page 221) first involves preparing a dry powder mixture of both zinc oxide and mercuric oxide. A binding agent such as PVA is added to the mixture prior to application on the grids which are held in place by separate molds. Both the grids and powder mixture are compressed and the resulting plaques are immersed in potassium hydroxide solution. The plaques are electrochemically formed and subsequently rinsed and dried.

The slurry paste processing method as illustrated in Figure V-29 (Page 222) involves preparing a slurry of zinc oxide, mercuric oxide, and either water or dilute potassium hydroxide. A binding agent such as CMC may be combined with the slurry. Once the slurry is prepared, it is layered on the surface of either a silver or copper screen and the material is allowed to dry prior to formation. The plates are immersed in a potassium hydroxide solution and formed against either positive electrodes or nickel dummy electrodes. After completion of formation, the anodes are thoroughly rinsed to assure removal of potassium hydroxide. The plaques are dried and later compressed to eliminate irregularities such as jagged edges.

Four plants reported using either the pressed powder or pasted slurry technique for zinc anode manufacture. The only source of discharge is the post-formation rinse operation. Since the raw materials are comparable for both techniques of preparing the plaques, the pollutant characteristics for the rinse water discharges are similar. The discharge flow rate of the post-formation rinse based on weight of zinc applied in anode formulation ranges from 33.3 to 277.3 l/kg (142.4 l/kg mean and 116.7 l/kg median). The rinse water waste stream was sampled at two of these facilities, Plants A and B. One plant, C, is excluded from the flow analysis because the required data were not provided in the dcp. At Plant B, plaques are rinsed in a multistage countercurrent rinse after formation.

As previously mentioned, the post-formation rinse wastewater was sampled at both Plants A and B. The analysis results for each sample day are presented in Table V-80 (Page 340). Table V-81 (Page 341) presents the pollutant mass loadings from anode preparation on a daily basis. Tables V-82 and V-83 (Pages 342 and 343) show the statistical

analysis of the raw waste data in units of mg/l and mg/kg, respectively.

Electrodeposited Zinc Anode - This process involves electrodepositing zinc on a grid and rinsing prior to amalgamation by deposition of mercuric salts. Afterwards, the plaques are either immediately dried or rinsed and then dried.

The most common grid materials used in the electrodeposition process include silver and copper expanded sheets. The grids are immersed in an aqueous solution of potassium hydroxide and zinc, and an electrical current is applied causing the zinc to deposit onto the grids. When the appropriate weight gain of active material on the grids is achieved, the grids are removed from the caustic solution and subsequently rinsed in a series of tanks. At an intermediate point in the rinsing procedure, the moist material may be compressed resulting in wastewater which combines with the rinse wastewater. After completion of the rinse operation, the prepared plaques are dipped in an acidic solution containing mercuric chloride. Mercury is reduced and deposits on the surface forming an amalgam with the zinc. The amalgamated plaques are either rinsed and subsequently dried or immediately dried following amalgamation. Figure V-30 (Page 223) is a schematic diagram of the entire electrodeposition process.

Two plants (A and B) in the data base reported using the zinc electro-deposition process. The resultant wastewater was sampled at Plant A. Based on the data received in the survey for Plant B and the visit data for Plant A, the discharge flows range from 1420.7 to 4966.9 liters per kilogram of zinc applied during the electrodeposition operation. The process waste streams associated with the manufacture of electrodeposited anodes include (1) post-electrodeposition rinses, (2) amalgamation solution dump, and (3) post-amalgamation rinse. The first two waste streams were sampled at Plant A, and the remaining waste stream was not sampled because the process at that facility does not require a rinse following the amalgamation step.

At Plant A, the post-electrodeposition rinse flows are higher than at Plant B because the latter plant has implemented a countercurrent rinse system. The post-electrodeposition rinse operation which was sampled at Plant A has a discharge flow ranging from 4655.6 to 5368.3 l/kg (4965.3 l/kg mean and 4871.9 l/kg median) which exceeds by at least a factor of four the discharge flow for the same rinse operation at Plant B. Ninety-seven percent of the total electrodeposition process wastewater at both facilities results from post-electrode-position rinsing. The most significant pollutant in the sampled rinse waste stream is zinc resulting from poorly-adherent zinc particles which are removed from the product by rinsing and compressing between the rinsing phases.

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The other waste stream at Plant A which is associated with the zinc electrodeposition process is the amalgamation solution dump. At this facility, the amalgamation solution is dumped after sixteen hours of operation of a single electrode-position line. The resulting normalized discharge flow averages one liter per kilogram of zinc applied. Table V-84 (Page 344) presents chemical characteristics of the total wastewater discharge resulting from the production of electrodeposited zinc anodes. For the first and third days, these characteristics were determined by mass balance calculations from the measured characteristics of the electrodeposition rinse and amalgamation solution waste streams. In addition, the pollutant mass loadings on each sample day are presented in Table V-85 (Page 345.).

Cathode Operations

Porous Carbon Cathode – The production of porous carbon cathodes involves the combination of powdered carbon, manganese dioxide, and water to form "agglos" or agglomerates of active cathode material. These agglos are assembled with cast zinc anode plates to manufacture carbon-zinc air cells.

Two plants reported manufacturing porous carbon cathodes. No wastewater is discharged from this cathode manufacturing process at either of these plants.

Manganese Dioxide-Carbon Cathode – Cathodes in this group are produced by blending manganese dioxide with carbon black, graphite, cement, and for some special cells, mercuric oxide. Typically the cathode mixture is inserted in steel cans along with separator material, and electrolyte solution consisting of potassium hydroxide is subsequently added to the partly assembled cells. At some plants, electrolyte solution is blended with the cathode material, and the resulting mixture is molded into cylindrical structures prior to insertion in the steel cans. The separator material is placed into the interior of each can, and additional electrolyte solution is then applied.

Nine plants reported producing manganese dioxide carbon cathodes for alkaline-manganese cell manufacture. Three of these plants have since discontinued the production of alkaline-manganese cells.

The processes used to formulate the cathode material do not generate any wastewaters.

Mercuric Oxide (And Mercuric Oxide-Manganese Dioxide-Carbon) Cathodes – Mercuric oxide is the principle depolarizer material for cathodes in this element. The cathode mixture is pelletized and placed in steel containers to produce mercury (Ruben) cells.

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The four plants presently producing this cathode are mercury cell manufacturers that blend mercuric oxide with other raw materials in formulating cathodes. Depending on battery specifications, the mercuric oxide is blended with a variety of other materials including graphite and manganese dioxide. The cathode formulation process generates no process wastewater since the blended and pelletized materials are in dry powdered forms.

Mercuric Oxide-Cadmium Oxide Cathode - The cathodes assigned to this element are produced by blending mercuric oxide, manganese dioxide, graphite, and cadmium oxide. The mixture is then pelletized and placed in steel cans. One plant reported using this method to manufacture cathodes. No wastewater is generated from this cathode process.

Silver Powder Pressed Cathode - This grouping includes cathodes produced by the application of silver powder onto grids. Cathodes in this group are formed after assembly into cells. Silver powder (sometimes produced on-site) is pressed on the surface of a silver screen or other support material and the pressed product is sintered to prepare the plaques for assembly. No process water is used and no wastewater discharge results from the production of these cathodes.

Silver Powder Pressed and Electrolytically Oxidized Cathode - The manufacture of these cathodes involves the use of silver powder which is either purchased or produced on-site. Once the silver powder is prepared, the material is pressed on the surface of a silver grid or other support material and subsequently sintered. Next, the sintered plaques are immersed in potassium hydroxide solution and subjected to an electrical charge-discharge operation which converts the silver material to a silver oxide state. After completing this process, the formed plaques are rinsed to remove any residual caustic. Figure V-31 (Page 224) is a schematic diagram of this process.

Three plants reported pressing silver powder on grids to produce sintered plaques which are subsequently formed. The post-formation rinse wastewater was sampled at both Plants A and B. Table V-86 presents the normalized discharge flows which range from 79.7 to 1135.5 liters per kilogram of silver powder applied to the grid material. With the value for the second day at Plant A eliminated because of variability observed with floor area maintenance water use, the mean and median normalized flow is 196.25 l/kg. The post-formation rinse is the only source of wastewater from the manufacture of these cathodes. Analysis results are presented in Table V-87 (Page 347).

Table V-88 (Page 348) presents the daily pollutant mass loadings of both facilities and statistical analyses in units of mg/l and mg/kg

are presented in Table V-89 and V-90 (Pages 349 and 350), respectively.

Silver Oxide (Ag₂O) Powder Cathodes - This process involves blending powdered raw materials to formulate cathodes used in button cell manufacture. The cathode powder mixture depends on engineering specifications and may include such materials as manganese dioxide, graphite, magnesium oxide, mercuric oxide, and binders blended with silver oxide powder. When the cathode mixture is prepared, the material is pelletized and inserted into the cell containers.

Four plants reported manufacturing cathodes in this group. No wastewater is generated from this process since the materials are combined in the dry powdered state and further processing, involving pelletizing and insertion in the cell container, is executed under dry conditions.

Silver Oxide (Ag₂O) Powder - Thermally Reduced or Sintered, Electrolytically Formed Cathode - Cathode formulation using this process involves preparing a slurry paste of silver oxide powder and deionized water and layering the mixture on silver metal grids. The reinforced material is thermally reduced to silver by applying heat sufficient for sintering. The resulting plaques are positioned in tanks containing dilute potassium hydroxide solution, electrically formed, rinsed and soaked until the engineering specifications are met. Figure V-32 is a schematic diagram of this process which indicates the wastewater discharge locations.

Two plants reported using this process. The normalized wastewater flow rates for these plants ranged from 25.0 to 237.1 liters per kilogram of silver in the silver oxide applied to the grid material. These plants reported that wastewater discharges result from slurry paste preparation, formation, and post-formation rinsing. However, Plant A reported data only for post-formation rinsing (corresponding to the 25.0 l/kg), and Plant B reported data only for spent formation solutions and post-formation rinses (corresponding to the 237.1 l/kg).

Two samples were taken which together represent an entire post-formation rinse cycle. The rinse cycle at Plant B has two phases. The first phase involves rinsing the plaques for approximately an hour while they are still positioned inside the formation tanks, and the second phase involves removing the plaques from the tanks and subsequently submerging them in water to soak for approximately 24 hours. The analysis results of the post-formation rinse wastewater (both phases) are presented in Table V-91 (Page 351) and the pollutant mass loading estimates are presented in Table V-92 (Page 352). The wastewater of the first phase of the post-formation rinse operation was sampled on the second day and the discharge flow was 437.3 l/kg.

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This waste stream is highly alkaline due to the residual formation caustic.

The second phase of the rinse cycle was sampled on the third day during which the normalized discharge flow was 100.9 l/kg. The significant pollutants in this waste stream are mercury and silver. The higher silver concentration in the wastewater of the second rinse phase compared to that reported for the first phase is due to the fact that a smaller volume of water is contacting the surface of the plaques for a considerably longer time span.

Silver Peroxide (AgO) Cathodes - Cathode preparation follows the manufacture of silver peroxide powder, which is a separate ancillary operation. Two cathode preparation processes are in current practice. Two plants use a chemical treatment process, and one plant uses a slurry pasting process.

The chemical treatment process starts with pelletizing of the silver peroxide powder. These cathode pellets are then chemically treated in two-phases; first in a concentrated potassium hydroxide solution; and then in a concentrated potassium hydroxide-methanol mixture. After rinsing and extended soaking in potassium hydroxide, the pellets are treated with a solution of hydrazine and methanol for the purpose of metallizing the surface. Figure V-33 (Page 226) is a schematic diagram of the process involving chemical treatment of silver peroxide pellets.

Process waste streams are associated with the first phase of chemical treatment. The wastewater results from (1) spent potassium hydroxide and methanol bath dumps, (2) rinsing, and (3) soaking. Two plants (A and B) reported chemically treating silver peroxide pellets. The normalized discharge flow from this chemical treatment phase range from 5.6 to 12.8 liters per kilogram of silver processed. The latter value represents the average discharge flow observed during the sampling visit at Plant B. Observed daily discharge flow range from 5.5 to 22.4 l/kg. Table V-93 (Page 353) presents the analysis results of the wastewater sampled at Plant B which is a combination of both the spent solution dump and subsequent rinse wastewater. Analytical results vary throughout the three sampling days due to the batch discharge nature of the processes and the one-hour sampling interval.

Another method currently used to produce silver peroxide cathodes involves mixing a slurry of silver peroxide powder, deionized water, and a binding agent such as carboxymethylcellulose. The slurry paste is layered on the surface of a silver metal grid and subsequently dried. The only wastewater from this process is from the clean-up of utensils used to mix the slurry and apply the material on support material. Figure V-34 (Page 227) is a schematic diagram of this process.

Plant C reported manufacturing reinforced silver peroxide cathodes. The resultant wastewater was sampled at this facility which produced a normalized discharge flow for the sample day of 76.0 liters per kilogram of silver processed. This flow varies according to the operator's discretion in the amount of water used to wash the utensils. Table V-93 (Page 353) presents the results of analysis of the wastewater from the utensil wash operation at Plant C.

Table V-94 (Page 354) presents the pollutant mass loadings in the process waste streams of both Plants C and B. These data are the basis for the statistical summary of wastewater characteristics from processes for producing silver peroxide cathodes. The waste streams resulting from both pellet chemical treatment and slurry application on support material are summarized in the statistical analyses presented in Tables V-95 and V-96 (Pages 355 and 356).

Nickel Impregnated Cathodes - Sintered cathodes which are then impregnated and formed are used to manufacture nickel-zinc batteries. Discussion and analyses of the impregnated nickel cathode is under the cadmium subcategory. Table V-22 (Page 276) and Table V-23 (Page 277) present the results of the analyses in terms of concentrations and mass loadings.

Ancillary Operations

Cell Wash - After completion of both anode and cathode manufacture, the cells are assembled; washing alkaline electrolyte is added; the cells are sealed; and the cells are washed to remove residual electrolyte and clean the metallic cell surface of other contaminants. There are a variety of cell washing systems including both manual and automatic types and cleaning agents including solvents, compounds and plain water.

Cell wash operations presently conducted at the seven facilities reporting cell wash operations can be assigned to one of five groups based on the chemicals used to wash the cells. This scheme is used as a framework for describing each of the cell wash operations. These groups are (1) acetic acid cell wash, (2) cleaning compounds (usually chromic acid containing) cell wash, (3) methylene chloride cell wash, (4) freon cell wash; and (5) plain water cell rinse. Within each group there is at least one plant in which the cell wash operation wastewater was sampled.

The first grouping listed involves the use of acetic acid in the preliminary phase of the cell wash operation. The sealed cells are immersed in a solution consisting of acetic acid with an unspecified detergent. Afterwards, the cells are transferred from the acidic solution to a potassium hydroxide solution; thoroughly rinsed to remove any remaining chemical used to clean the cells; and dipped in a

solution containing an oil base additive. Two plants reported using this technique for cleaning cells.

The second general grouping involves the use of cleaners; usually containing chromic acid. Rinsing occurs after washing these cells. Four plants in the data base reported using cleaners containing chromic acid and wastewater from three of these cell wash operations was sampled.

The third cell wash grouping involves submerging the cells in a series of tanks containing methylene chloride, methyl alcohol and ammonium hydroxide. The wastewater from one plant which used this process to wash cells was sampled.

The fourth cell wash group uses freon to clean cell surfaces. Two plants presently use freon in the cell wash operations.

In the fifth cell wash group, only water (no chemical) was reported to be used to clean the cell container surfaces. Two plants are in this group, and samples were taken at one plant.

A total of seven plants reported using a cell wash operation in the manufacture of zinc subcategory cells. The production normalized discharge flows are determined for each of the seven plants by using data either obtained in the dcp's or during sampling visits. Table V-97 (Page 357) presents the normalized discharge flows from cell wash operations at Plants A-G. Based on these data, the range is 0.09 to 34.1 liters per kilogram of finished cells (6.35 1/kg mean and 0.34 1/kg median). The large observed discharge flow variations from cell wash operations may be related primarily to differences in plant water conservation practices although cell size and plant specific washing procedures are also observed to have an influence.

Table V-98 (Page 358) presents the data from sampling cell wash operation wastewaters at four plants. All of the cell wash groups are represented. In the table all of the waste streams from cell wash operations that were sampled at each facility are combined on a flow-proportioned daily basis to achieve complete plant-by-plant raw waste characterizations from cell washing.

Table V-99 (Page 359) presents the pollutant mass loadings on a daily basis for each facility. Statistical summaries are presented in Tables V-100 and V-101 (Page 360). The normalized discharge flows range from 0.085 to 1.8 liters per kilogram. The low value reflects a recirculating wash operation and the high value is a composite of wastewaters from three cell wash operations at one plant.

<u>Electrolyte</u> <u>Preparation</u> - Wastewater is generated from washing equipment used to prepare and apply electrolyte to the zinc

subcategory cells. Nine plants reported using water to formulate electrolyte solution which generally consists of dilute potassium hydroxide. One plant reported using sodium hydroxide solution as a substitute electrolyte for potassium hydroxide solution in the manufacture of certain cells. Two facilities both reported adding zinc oxide to the electrolyte solution.

Five plants reported no wastewater discharge from electrolyte processing. However, the remaining four plants did report wastewater discharges from electrolyte formulation primarily resulting from utensil washing. Table V-102 (Page 362) presents the analytical results of the waste stream sampled at Plant A. The measured flow is 0.37 liters per kilogram of finished cells processed during the sampling day.

Based on both the visit and dcp data, the wash-up operation associated with the preparation of electrolyte solution generates minimal wastewater (mean normalized flow of 0.12 l/kg and median normalized flow of 0.0 l/kg). The observed pollutant mass loadings of the sampled waste stream at Plant A as presented in Table V-103 (Page 363) do not contribute substantially to the total cell manufacture raw waste.

Silver Etch Process - The silver etch process prepares silver basis material for use in the zinc electrodeposition process. The silver foil is etched with nitric acid, rinsed and dried prior to electrodeposition. After use in the process, the nitric acid is collected in containers for contractor remove. Squeegees are used to wipe the etched silver foil surfaces before rinsing, and only residual acid contaminates the rinse wastewater.

The only wastewater discharge results from rinsing the etched silver foil. This waste stream was sampled at Plant A. The process is conducted on an intermittent basis depending on the production of silver oxide-zinc cell types requiring the etched material. The observed discharge flow is 49.1 liters per kilogram of silver processed.

Tables V-104 and V-105 (Pages 364 and 365) present the analytical results in units of mg/1 and mg/kg for the silver etch process wastewater. The pollutant characteristics of this acidic waste stream include zinc and silver. The presence of zinc probably results from process material contamination. The concentration of silver in the wastewater is high reflecting the absence of effective silver recovery measures.

Mandatory Employee Wash - For the purpose of ensuring health and safety, some facilities require the employees to wash before each break and at the end of each work day. Since process materials are

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removed during the wash operation, the resultant waste stream is considered process wastewater from the zinc subcategory.

Two plants (A and B) reported mandatory employee washing. Employee wash wastewater from both facilities was sampled. The composited sample taken at Plant B is a combination of wastewaters generated from washing clothes previously worn by process employees and from employee showers. However, a flow measurement was not obtained due to pipe inaccessibility. The analytical results are presented in Table V-106 (Page 366).

The employee wash wastewater was separately sampled at Plant A. The observed discharge flow is 0.27 liters per kilogram of finished cells. Table V-107 (Page 367) presents the analytical results of the wash waste stream. The most significant pollutants are suspended solids and oil and grease which are expected due to the employees handling both process materials and lubricated machinery. Table V-108 (Page 368) presents the pollutant mass loadings of the employee wash waste stream only from Plant A.

Reject Cell Handling - Inspections are performed throughout the cell assembly process. When a cell does not meet quality control specifications, it is removed from the process line for future repairs or disposal. If a cell can not be repaired, it is disposed as scrap. The disposal techniques implemented by the zinc subcategory cell manufacturers vary according to whether the materials composing the rejected cells require inactivation. By submerging certain cells in water, the active materials are discharged which lessens the potential fire hazard in both handling and disposal of these cells.

Three plants (B, C, and A) reported using water for handling reject cells. The discharge flows are minimal ranging from 0.002 to 0.03 liters per kilogram of finished cells (0.01 l/kg mean and 0.002 l/kg median). One plant contractor hauls the wastewater with the rejected cells to a landfill site whereas the other two plants treat the wastewater on-site.

At Plant A, the discharge flow was observed to be 0.03 liters per kilogram of finished cells. Table V-109 (Page 369) presents the analysis results of the reject cell handling waste stream. The significant pollutants are silver, zinc, and mercury.

The reject cell wastewater was also sampled at Plant B/ Analytical results for Plant B only are presented in Table V-110 (Page 370). This waste stream is characterized by a low discharge flow (0.003 liters per kilogram). The most significant pollutants observed are suspended solids, zinc, and mercury which are constituents of the alkaline cells being processed. Table V-111 (Page 371) presents the

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pollutant mass loadings of the data attained from sampling the reject cell wastewater at Plant B.

Floor Wash - Some facilities maintain process floor areas by using water to remove wasted process materials and other dirt. Only three plants reported using water for floor maintenance whereas the other plants generally use other means to clean the floors. These methods which do not involve water usage include vacuuming, dry sweeping, and applying desiccant materials in instances of solution spillages.

Each of the three plants that reported using water to clean process floor areas has a wastewater discharge from the cleaning operation. Two plants reported discharge flow estimates reflecting both floor area and equipment cleaning wastewater in their dcp's. Based on dcp estimates and the discharge flows observed during the sampling visit at Plant A which represents floor cleaning only, the range of discharge flows is 0.0008 to 0.30 liters per kilogram of finished cells (0.13 l/kg mean and 0.10 l/kg median).

Table V-112 (Page 372) presents the analytical results of the wastewater resulting from the floor wash operation at Plant A. Table V-113 (Page 373) presents the pollutant mass loadings based on the data obtained at Plant A.

Lead is a significant pollutant which apparently results from contamination with solder constituents used to attach tabs to the electrode substrate materials. In addition, suspended solids are high in the floor wash wastewater as is ammonia which is a chemical used to clean the floors.

Equipment Wash

Four plants in the data base reported using water to clean equipment used to manufacture zinc subcategory cells. All of these plants have wastewater discharges resulting from cleaning equipment used to handle process materials. As was previously cited in the floor wash discussion, two plants reported wastewater discharge estimates representing both equipment and floor cleaning. Separate equipment cleaning discharge flow estimates have been obtained in sampling the resultant wastewater at Plants A and B. At these two plants, the observed discharges range from 5.1 to 9.0 liters per kilogram of finished cells.

The significant pollutants in the equipment wash waste streams at Plant B include suspended solids, zinc, and mercury which result from the formation operation. Table V-114 (Page 374) presents the analytical results for equipment wash. The relatively high discharge flow occurred on the first sampling day because all of the equipment was washed.

The same table shows the analytical results from the sample visit of Plant A. The wastewater at this facility is generated from equipment wash operations with occasional employee hand washing. The observed flow is 5.1 liters per kilogram of finished cells. The significant pollutants in this waste stream are suspended solids, mercury, and zinc which result from process material contamination.

Table V-115 (Page 375) presents the pollutant mass loading calculated from the analysis data from both Plants A and B. Statistical summaries of both the concentration and loading data are presented in Table V-116 and V-117 (Pages 376 and 377), respectively.

Silver Powder Production - Silver powder for use in battery cathodes is manufactured by electrodeposition and mechanical removal. The slurry which results is filtered to recover the silver powder, and the filtrate is returned for continued use in the electrodeposition process. The wet silver powder is rinsed to remove residual acid and dried prior to storage or use in cathode manufacture.

Process wastewater from the product rinse step was characterized by sampling at Plant A. Observed wastewater discharge flows range between 19.8 and 23.7 l/kg (21.2 l/kg mean and 20.1 l/kg median). The results of analyses of samples from this wastewater source are presented in Table V-118 (Page 378). Table V-119 (Page 379) presents corresponding pollutant mass loading data.

Silver Peroxide Production - Silver peroxide is produced by two chemical oxidation processes from silver oxide or silver nitrate. Oxidants used are ozone and potassium persulfate.

The results of analysis of wastewater samples from peroxide production are presented in Table V-120 (Page 380:) and corresponding pollutant mass loadings in Table V-121 (Page 381).

Total Subcategory Wastewater Characteristics

Total process wastewater characteristics have been estimated for the zinc subcategory by chemical analysis of waste streams from each process element. These wastewater values are summarized in a single table weighted according to the amount of each element manufactured in the subcategory.

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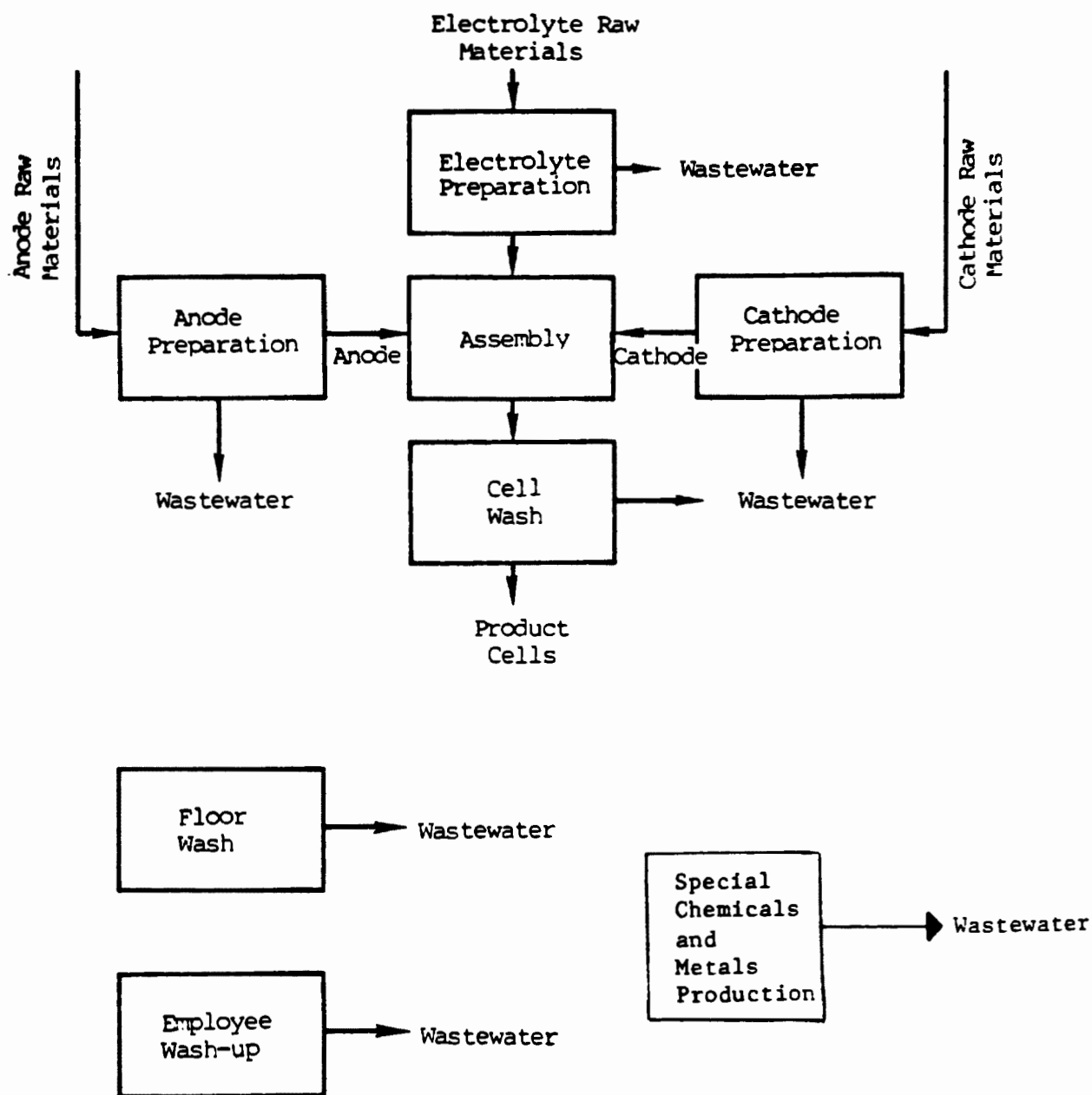
FIGURE V-1

GENERALIZED CADMIUM SUBCATEGORY MANUFACTURING PROCESS

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FIGURE V-2

CADMIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Anode Manufacture	Pasted and Pressed Powder	. Process Area Clean-up
	Electrodeposited	. Product Rinses . Spent Caustic . Scrubbers
	Impregnated	. Sintered Stock Preparation Clean-up . Impregnation Rinses . Spent Impregnation Caustic . Product Cleaning . Pre-formation Soak . Spent Formation Caustic . Post-formation Rinse
Cathode Manufacture	Silver Powder Pressed	. No Process Wastewater
	Nickel Pasted and Pressed Powder	. No Process Wastewater
	Nickel Electrodeposited	. Spent Caustic . Post-formation Rinse
	Nickel Impregnated	. Sintered Stock Preparation Clean-up . Impregnation Rinses . Impregnation Scrubbers . Product Cleaning . Pre-formation Soak . Spent Formation Caustic . Post-formation Rinses . Impregnation Equipment Wash . Nickel Recovery Filter Wash . Nickel Recovery Scrubber
Ancillary Operations	Cell Wash	. Cell Wash

FIGURE V-2 (CON'T)

CADMIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Ancillary Operations	Electrolyte Preparation	. Equipment Wash
	Floor Wash	. Floor Wash
	Employee Wash	. Employee Wash
	Cadmium Powder Production	. Product Rinses . Scrubber
	Silver Powder Production	. Refer to Zinc Subcategory Analysis (Figure V-26)
	Nickel Hydroxide Production	. Product Rinses
	Cadmium Hydroxide Production	. Seal Cooling Water

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Cadmium Nitrate, → Solution
Hydrogen Peroxide   Preparation

Grid → Electro-
         deposition

Water → Rinse → Rinse Wastewater
                       Discharge

Caustic Solution → Formation → Caustic Solution Process
                                         Reuse or Discharge

Water → Rinse → Rinse Wastewater
                       Discharge

Finished Anode
To
Assembly
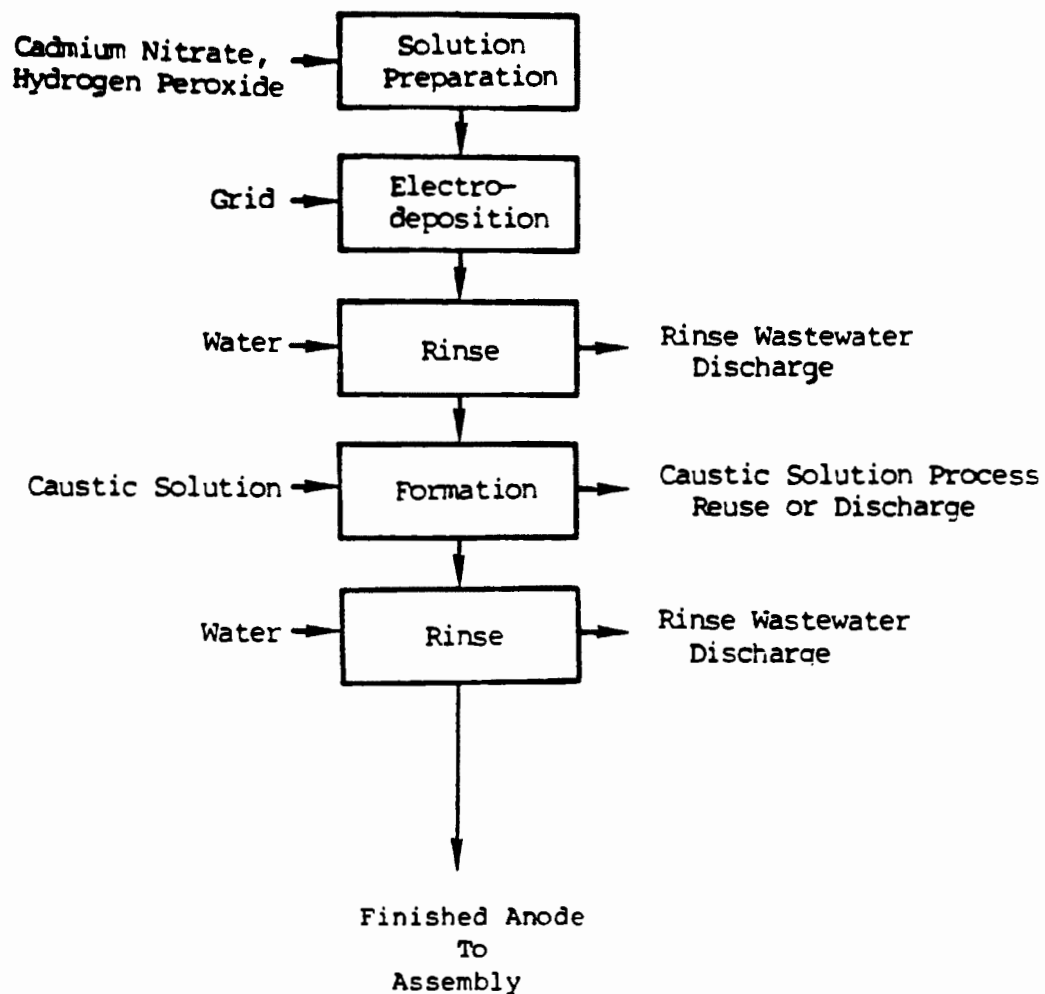
FIGURE V-3
PRODUCTION OF
CADMIUM ELECTRODEPOSITED ANODES

195

```
Cadmium Nitrate ──▶  ┌─────────────┐
                     │  Solution   │
                     │ Preparation │
                     └─────────────┘
┌──────────┐                │
│ Scrubbers │               ▼
└──────────┘         ┌─────────────┐
     │       Sintered Grids ──▶│ Impregnation │──┐
     ▼               └─────────────┘              │
Wastewater                  │                     │
                            ▼                     │
      Caustic Solution ──▶ ┌─────────────┐        │    To Reuse or Spent
                           │  Immersion  │───────────▶ Caustic Discharge
                           └─────────────┘        │
                                  │               │
                                  ▼               │
            Water ──▶ ┌─────────────┐◀────────────┘   Rinse Wastewater
                      │    Rinse    │──────────────▶  Discharge
                      └─────────────┘
                             │
                             ▼
            Water ──▶ ┌─────────────┐              To Reuse or Rinse
                      │  Cleaning   │────────────▶ Wastewater Discharge
                      └─────────────┘
                             │
                             ▼
  Caustic Solution ──▶ ┌─────────────┐              Spent Caustic
                       │  Formation  │────────────▶ Discharge
                       └─────────────┘
                              │
                              ▼
            Water ──▶ ┌─────────────┐              Rinse Wastewater
                      │    Rinse    │────────────▶ Discharge
                      └─────────────┘
                             │
                             ▼
              Finished Cathodes ──────▶  To
                                         Assembly
```

FIGURE V-4
PRODUCTION OF
CADMIUM IMPREGNATED ANODES

Nickel Nitrate, Cobalt Nitrate →

Solution Preparation

Grids →

Electrode-position

Caustic Solution →

Formation

→ Caustic Solution Process Reuse Or Discharge

Water →

Rinse

→ Rinse Wastewater Discharge

→ Finished Cathodes → To Assembly
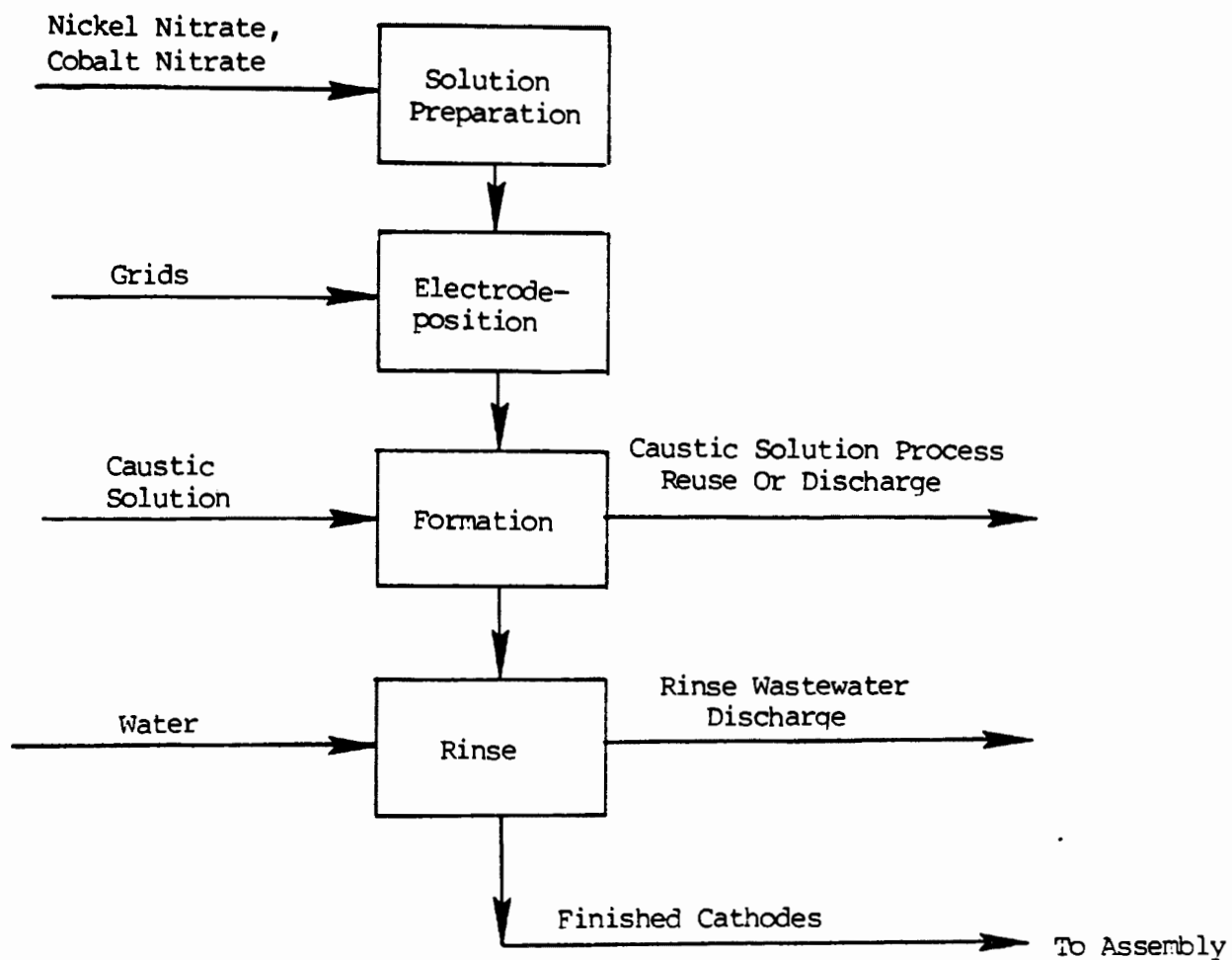
FIGURE V-5
PRODUCTION OF
NICKEL ELECTRODEPOSITED CATHODES

197
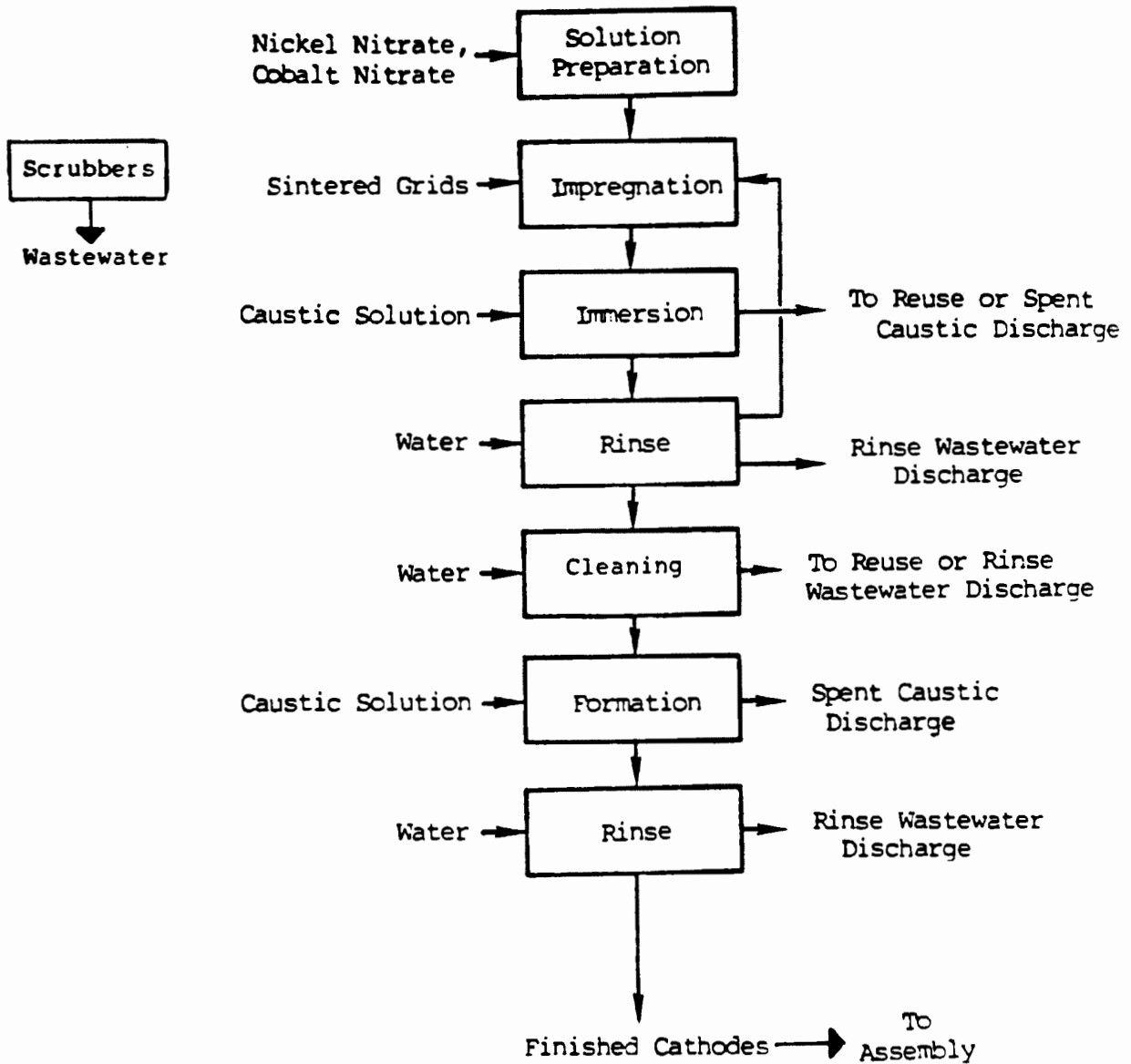
FIGURE V-6
PRODUCTION OF
NICKEL IMPREGNATED CATHODES

198

```
┌──────────────┐      ┌──────────────────┐
│ Blend De-    │      │ Heating Component │ ──→  Wastewater
│ polarizer    │      │   Preparation     │
│ And Elec-    │      └──────────────────┘
│ trolyte      │
└──────────────┘
       │                      │
       ▼                      ▼
┌──────────────┐      ┌──────────────┐      ┌──────────────┐
│ Depolarizer  │ ──→  │   Assembly   │ ←──  │    Anode     │
│ Preparation  │      │              │      │ Manufacture  │
└──────────────┘      └──────────────┘      └──────────────┘
                              │
                              ▼
                            Ship
```

```
┌──────────────┐
│    Cell      │ ──→  Wastewater
│   Testing    │
└──────────────┘
```
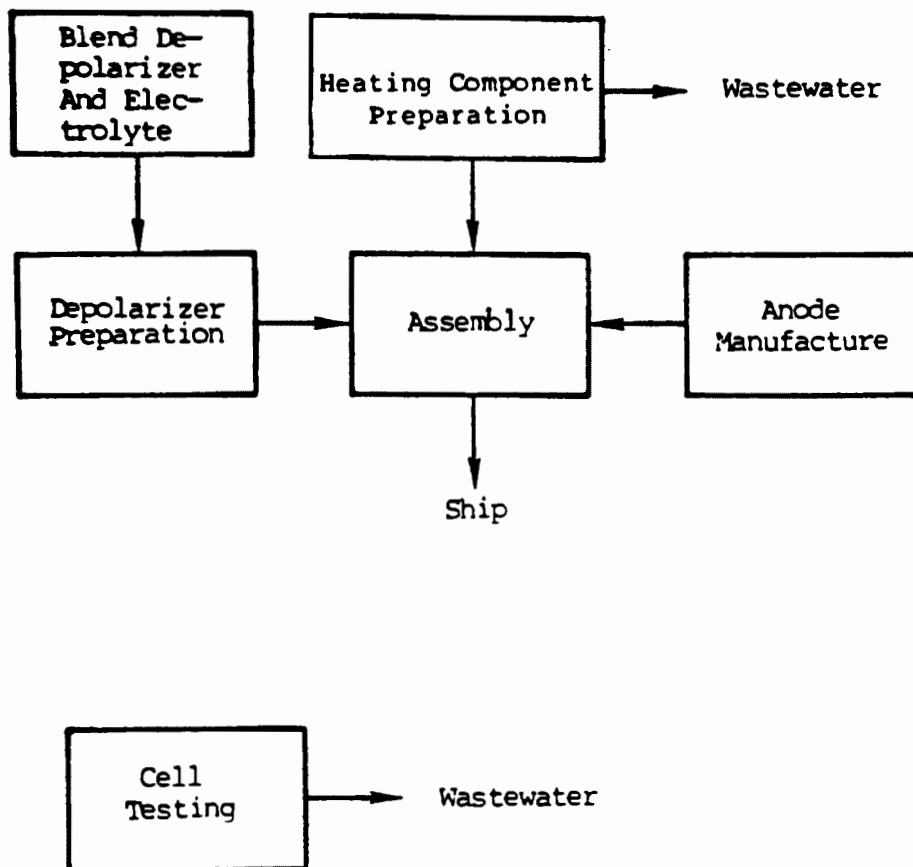
FIGURE V-7

GENERALIZED CALCIUM SUBCATEGORY
MANUFACTURING PROCESS

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FIGURE V-8

CALCIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Anode Manufacture	Vapor Deposited Fabricated	• No Process Wastewater
Cathode Manufacture	Calcium Chromate Tungstic Oxide Potassium Dichromate	• No Process Wastewater
Ancillary Operations	Heating Component Production: Heat Paper Heat Pellet	• Slurry Preparation • Filtrate Discharge • No Process Wastewater
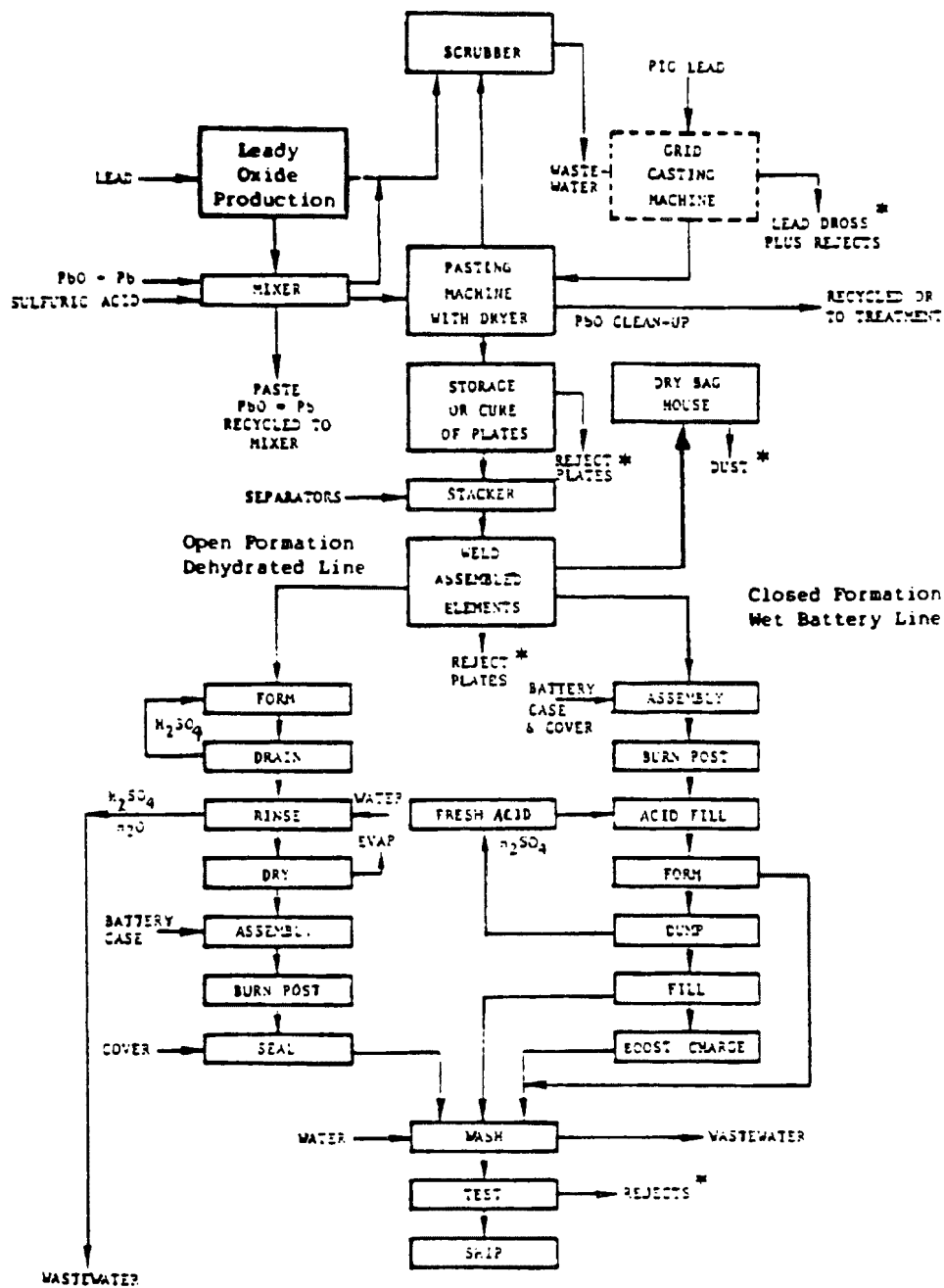
FIGURE V- 9
LEAD SUBCATEGORY
GENERALIZED MANUFACTURING PROCESSES

201

FIGURE V-10

LEAD SUBCATEGORY ANALYSIS

Process   Specific Wastewater Sources

Anodes and Cathodes

Leady   .Ball Mill Shell Cooling
Oxide Production   .Scrubber

Paste Preparation and   .Product Soak
Application   .Equipement and Floor Area
                                  Clean-up
                                 .Scrubber

Curing   .Steam Curing

Closed Formation (In Case)
   Single Fill   .Contact Cooling
                                 .Scrubber

   Double Fill   .Contact Cooling
                                 .Scrubber
                                 .Product Rinse
                                 .Formation Area Washdown

   Fill and Dump   .Formation Area Washdown
                                 .Product Rinse
                                 .Scrubber
                                 .Contact Cooling

Open Formation (Out of Case)
   Wet   .Scrubber
                                 .Formation Area Washdown

   Dehydrated   .Formation Area Washdown
                                 .Product Rinse
                                 .Vacuum Pump Seals and Ejectors
                                 .Scrubber

Ancillary Operations

Final Battery Wash   .Battery Wash

Floor Wash   .Floor Wash

Sinks and Showers   .Employee Wash

Battery Repair   .Battery Repair Area Wash
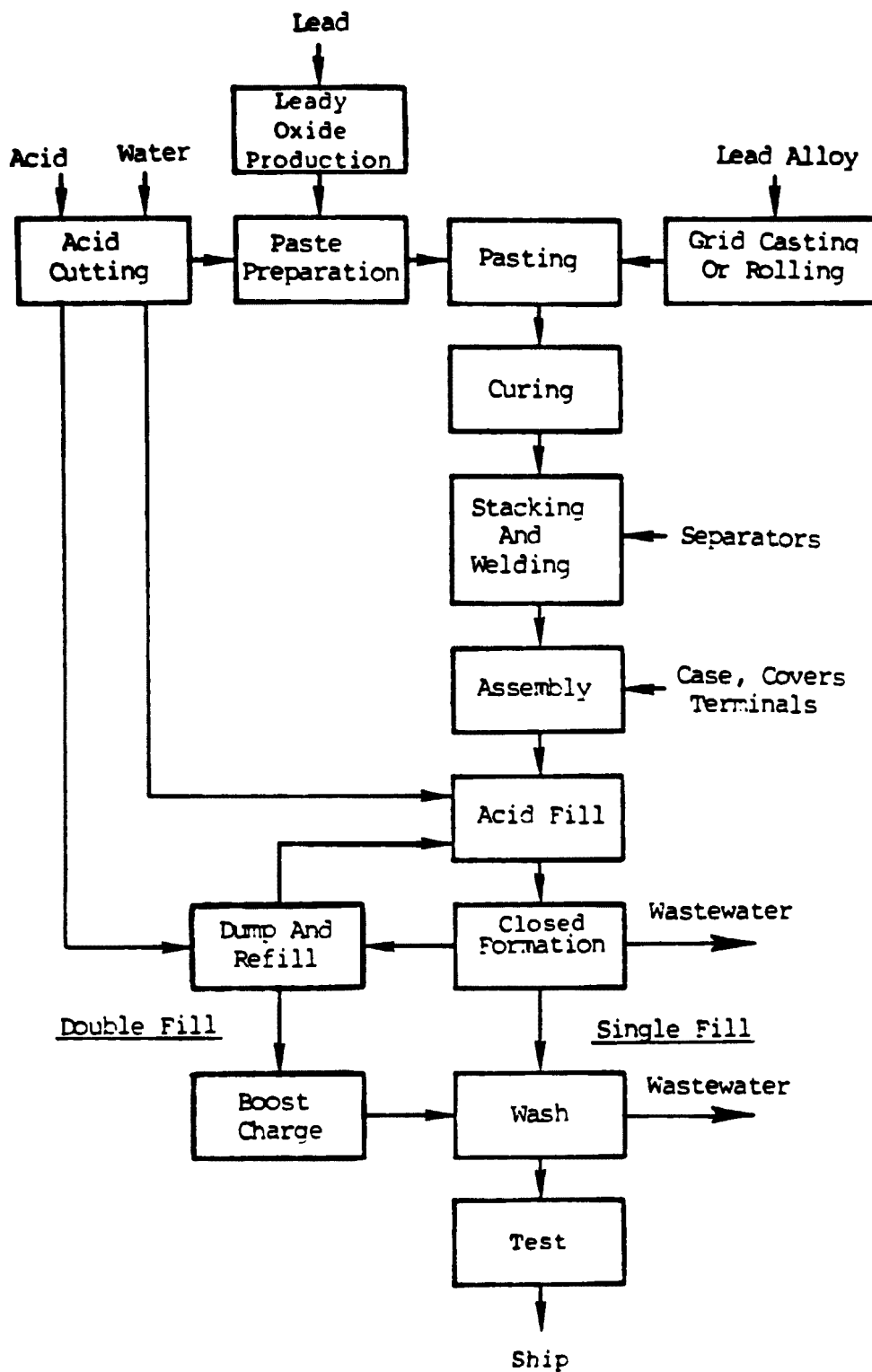
FIGURE V-11
PRODUCTION OF
CLOSED FORMATION WET BATTERIES
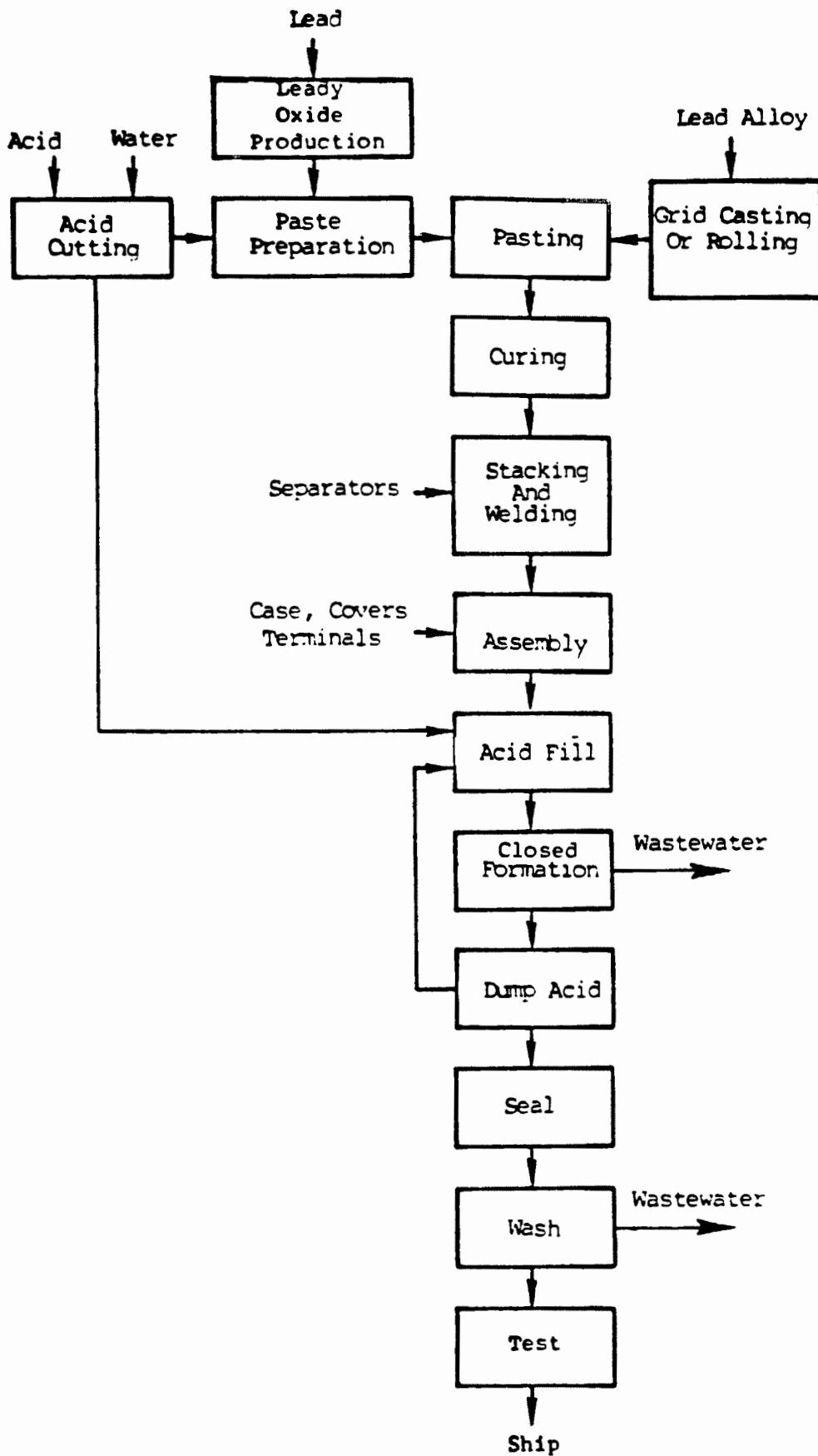
FIGURE V-12
PRODUCTION OF
DAMP BATTERIES

204

Lead

Leady
Oxide
Production

Acid   Water

Lead Alloy

Acid
Cutting → Paste
Preparation → Pasting ← Grid Cast-
ing Or
Rolling

Curing

Weld
Groups

Open
Formation

Rinsing
And
Dehydration → Wastewater

Separators, Cases,
Covers, Terminals → Assembly

Wash → Wastewater

Test

Ship
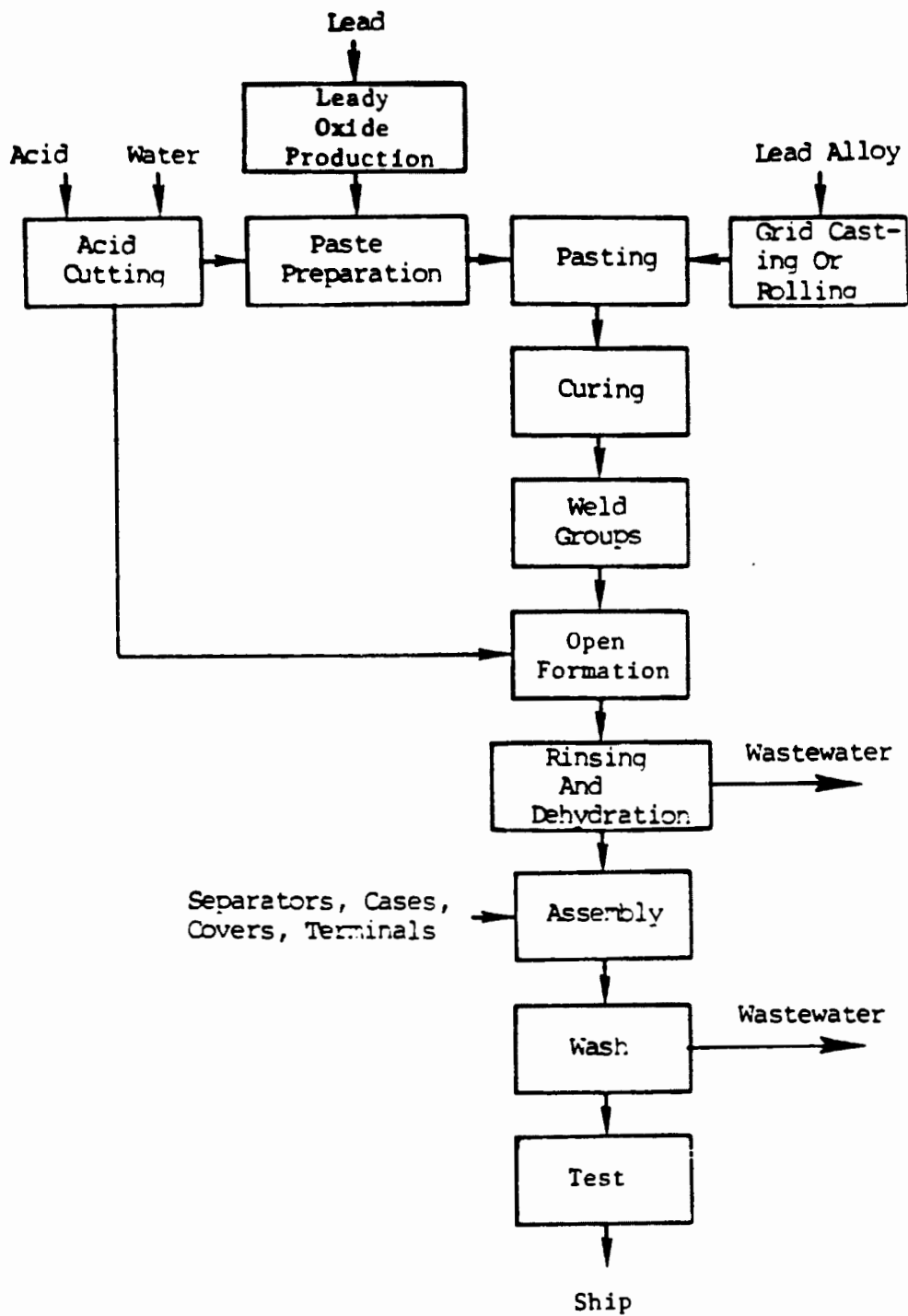
FIGURE V-1 3
PRODUCTION OF
DEHYDRATED BATTERIES

Purchased Green
Plates

Stacking
And   ◄— Separators
Welding

Acid   Water

Acid
Cutting

Assembly   ◄— Case, Covers
Terminals

Acid Fill

Dump And
Refill

Closed   Wastewater ——►
Formation

Double Fill   Single Fill

Boost   ——►   Wash   Wastewater ——►
Charge

Test

Ship
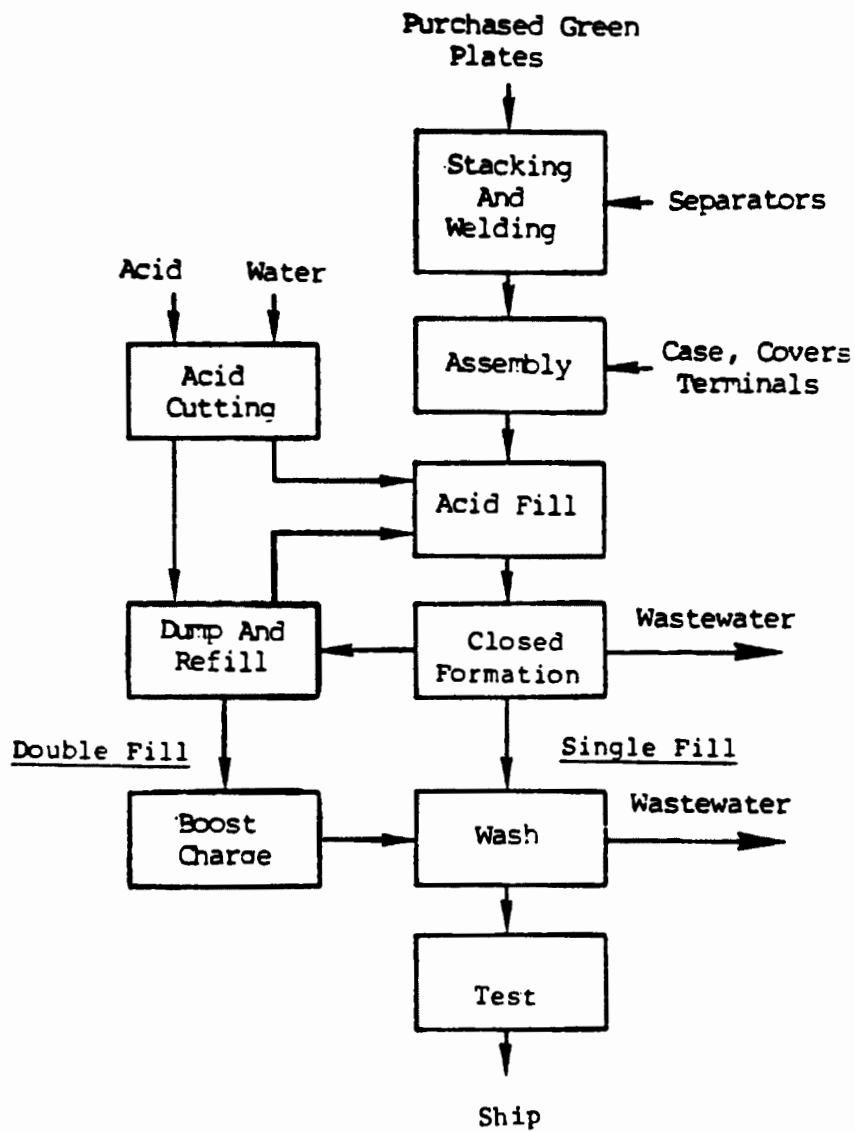
FIGURE V-14
PRODUCTION OF BATTERIES
FROM GREEN (UNFORMED) ELECTRODES
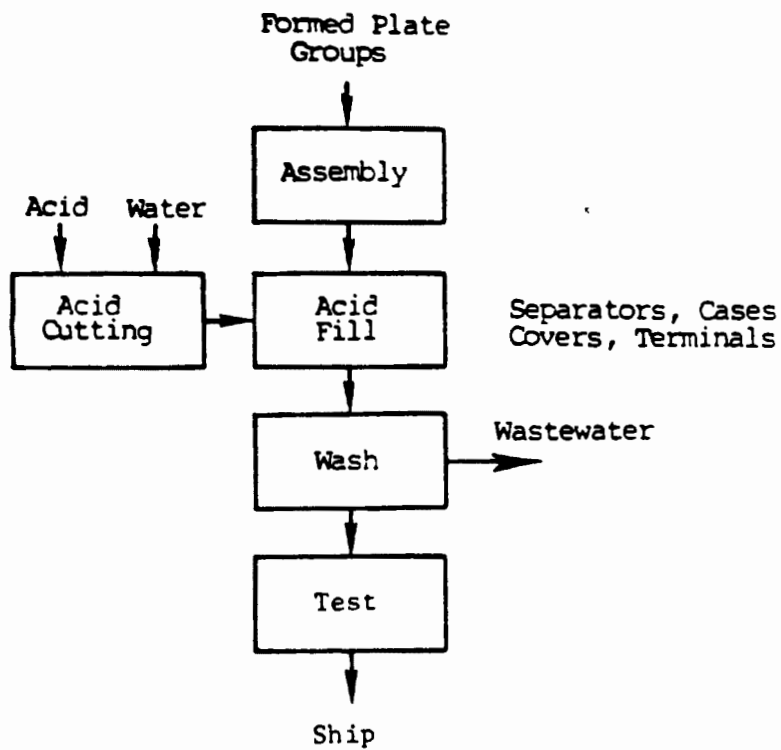
FIGURE V-15
PRODUCTION OF BATTERIES
FROM PURCHASED FORMED PLATES

Formation:	Median (Zeros Excluded)	Sample Median (Zeros Included)	Number Of Values	Number Of Zeros
Open Case:				
Shipped Wet	10.96	0	7	5
Dehydrated	10.25	9.0	35	2
Closed Case:				
Damp	1.032	0.83	11	2
Wet	0.635	0	88	57
Battery Wash	0.716	0.715	60	3
LeadyOxide Production	0.441	0	34	22
Pasting	0.330	0	95	51
Curing	0.0733	0	89	81
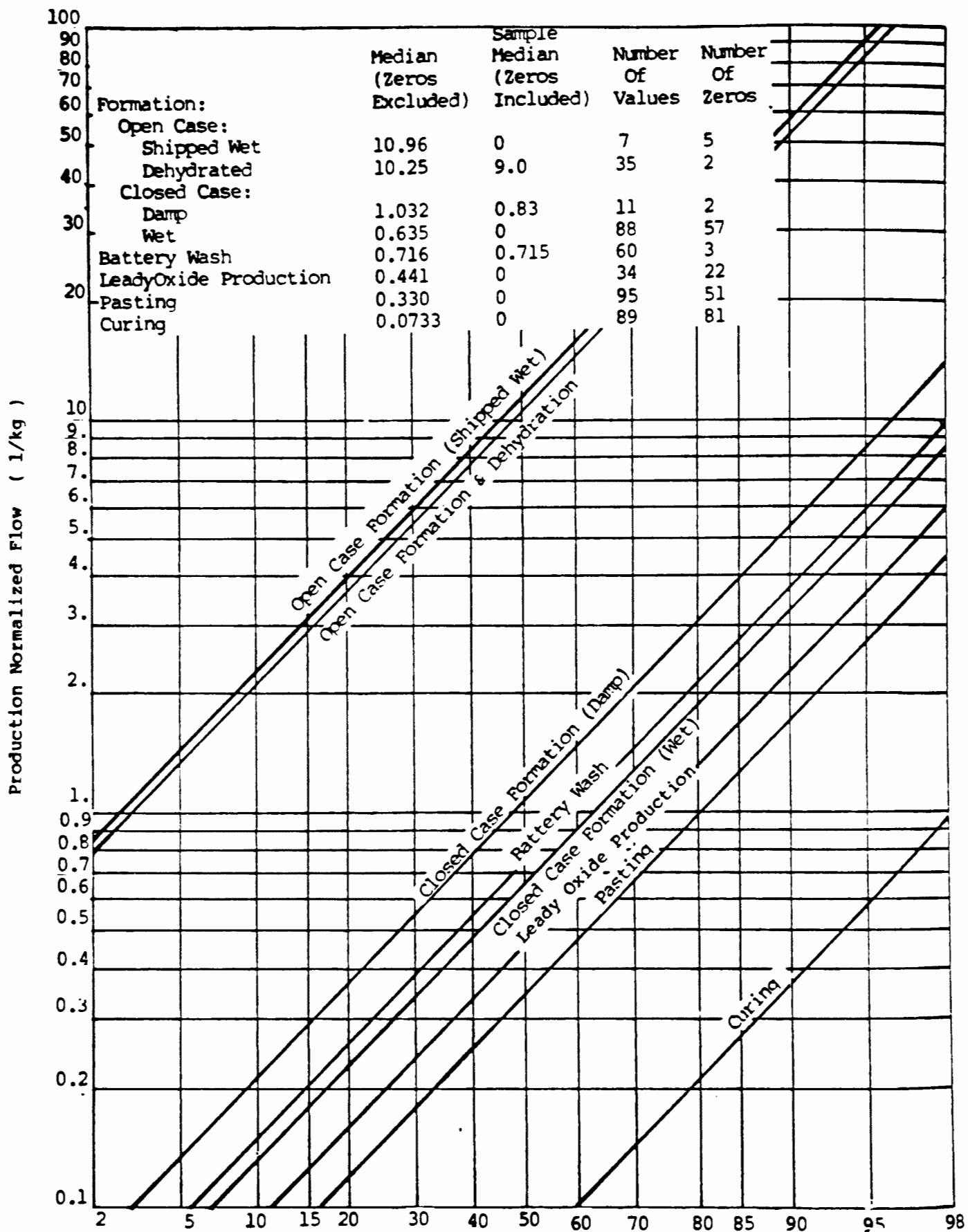
FIGURE V-16
PERCENT PRODUCTION NORMALIZED DISCHARGE FROM
LEAD SUBCATEGORY PROCESS OPERATIONS

Percent of Plants

208
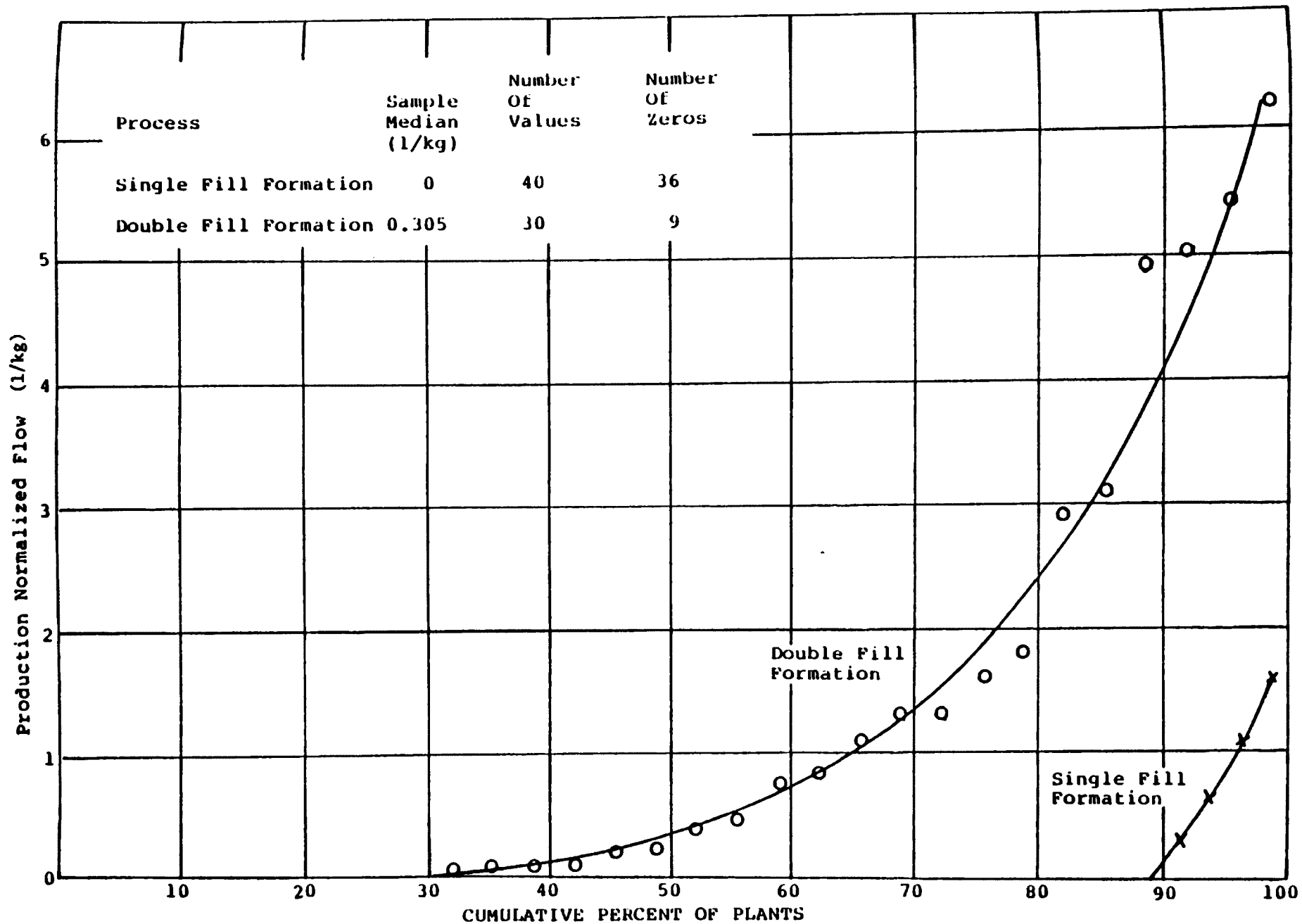
FIGURE V-17

PRODUCTION NORMALIZED DISCHARGE FROM DOUBLE AND SINGLE FILL FORMATION
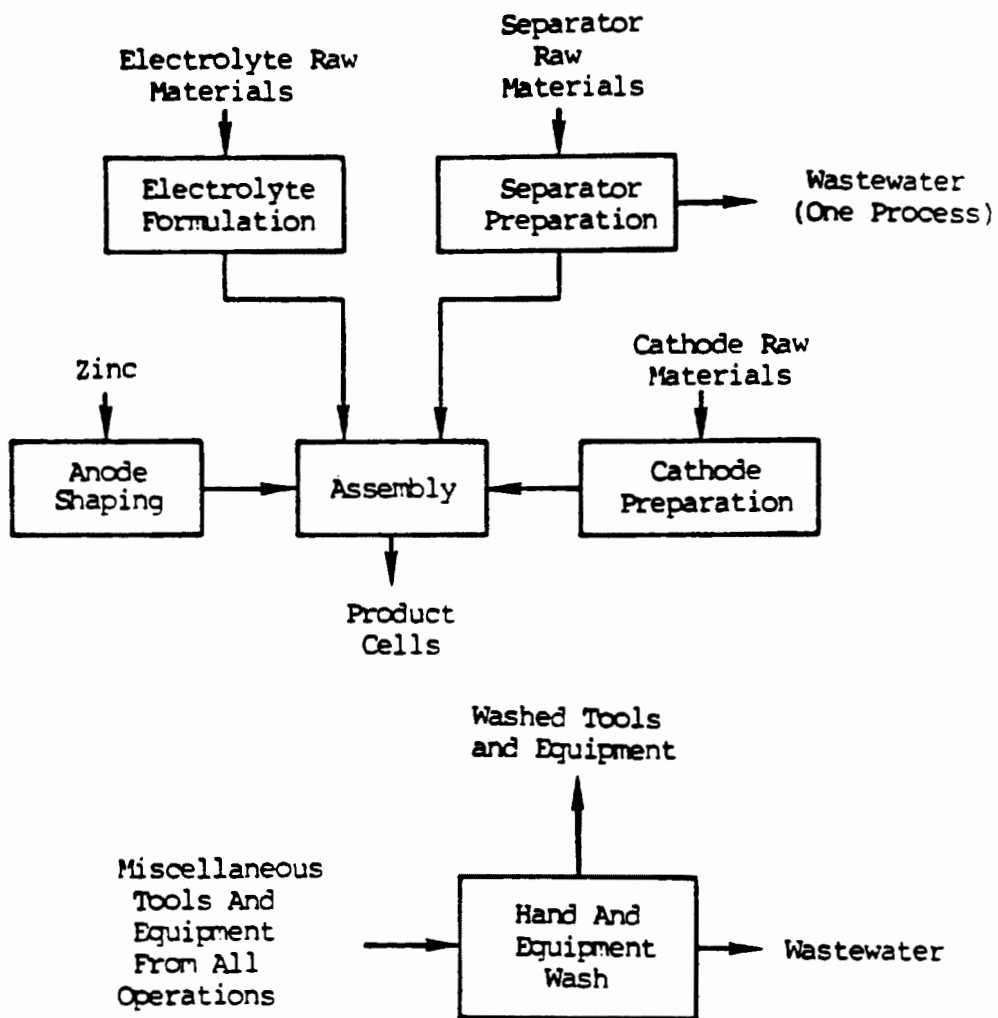
FIGURE V-18

GENERALIZED SCHEMATIC FOR
LECLANCHE CELL MANUFACTURE

FIGURE V-19

LECLANCHE SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources
Anode Manufacture	Zinc Powder	• No Process Wastewater
Cathode Manufacture	Manganese Dioxide - Pressed (All Formulations)	• No Process Wastewater
	Carbon (Porous)	• No Process Wastewater
	Silver Chloride	• No Process Wastewater
	Manganese Dioxide - Pasted	• No Process Wastewater

Ancillary Operations	Separators
	  Cooked Paste
	  Uncooked Paste
	  Pasted Paper
		• Paste Setting
		• Equipment Wash
		• Equipment Wash

	Equipment and Area Cleanup	• Electrolyte Preparation • Assembly Equipment Wash • Employee Wash • Electrode Preparation Equipment Wash • Miscellaneous Equipment Wash
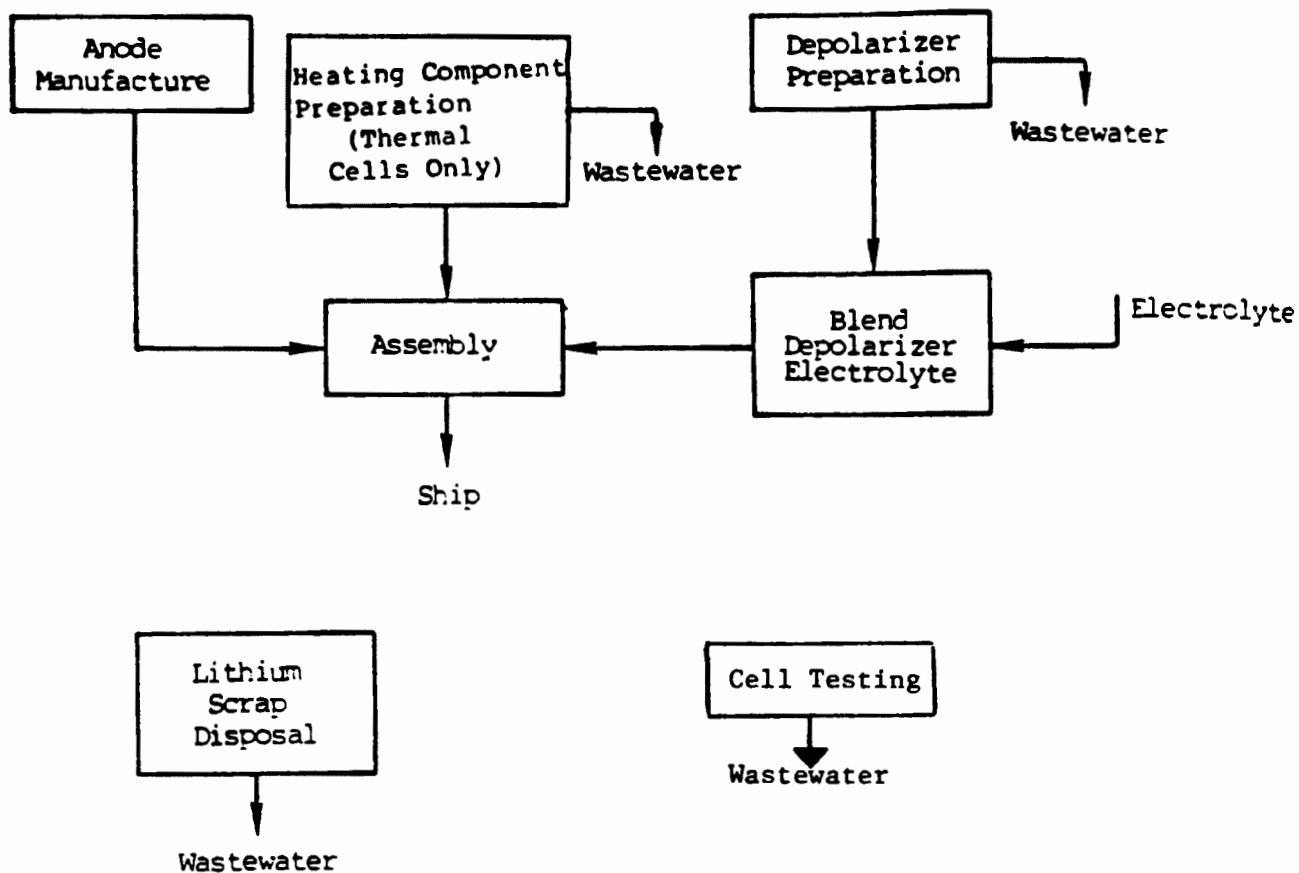
FIGURE V-20

GENERALIZED LITHIUM SUBCATEGORY
MANUFACTURING PROCESS

FIGURE V-21

LITHIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources (Subelements)
Anode Manufacture	Formed and Stamped	.No Process Wastewater
Cathode Manufacture	Iodine	.No Process Wastewater
	Iron Disulfide	.Product Treatment
	Lead - Iodide	.To Be Resolved
	Lithium Perchlorate	.No Process Wastewater
	Sulfur Dioxide	.Scrubbers
		.Cleanup
	Thionyl Chloride	.Scrubbers
		.Spills
	Titanium Disulfide	.No Process Wastewater
Ancillary	Heating Component Production:	
	Heat Paper	.Filtrate Discharge
		.Slurry Preparation
	Heat Pellets	.No Process Wastewater
	Scrap Disposal	.Scrap Disposal
	Testing	.Leak Testing

214
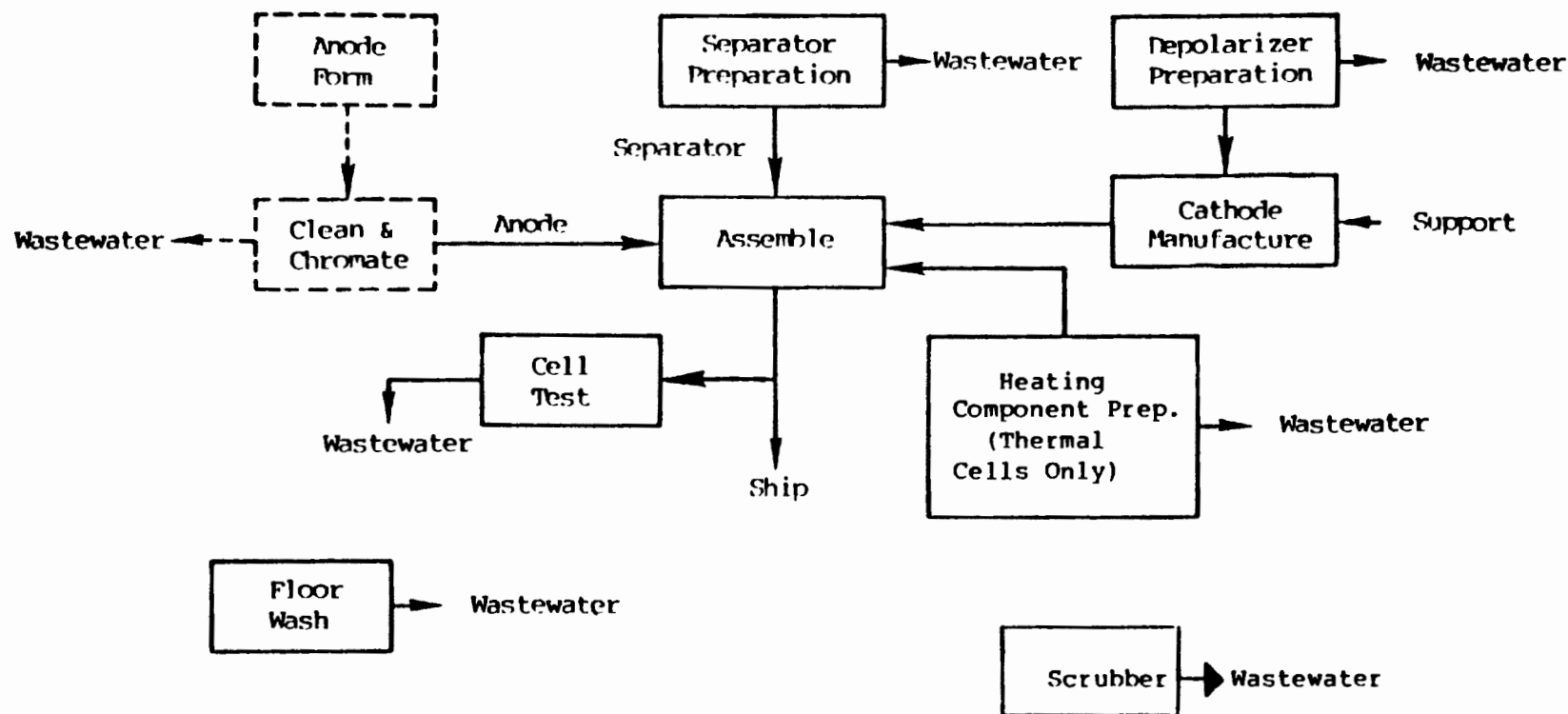
--- Operations Not Regulated In Battery
Manufacturing Point Source Category

FIGURE V-22

GENERALIZED MAGNESIUM SUBCATEGORY
MANUFACTURING PROCESS

FIGURE V-23

MAGNESIUM SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Source (Subelements)
Anode Manufacture	Magnesium Powder	.No Process Wastewater
Cathode Manufacture	Carbon	.No Process Wastewater
	Copper Chloride	.No Process Wastewater
	Copper Iodide	.No Process Wastewater
	Lead Chloride	.No Process Wastewater
	M-Dinitrobenzene	.No Process Wastewater
	Silver Chloride - Surface Reduced	.Product Rinsing
	Silver Chloride - Electrolytic Process	.Product Rinsing
	Silver Chloride	.No Process Wastewater
	Vanadium Pentoxide	.Scrubbers
Ancillary Operations	Heating Component Production: Heat Paper	.Filtrate Discharge
		.Slurry Preparation
	Testing	.Activation of Sea-Water Reserve Batteries
	Separator Processing	.Etching Solution
		.Product Rinsing
	Floor Wash	.Floor Wash
	Scrubbers	.Air Dehumidifiers

215
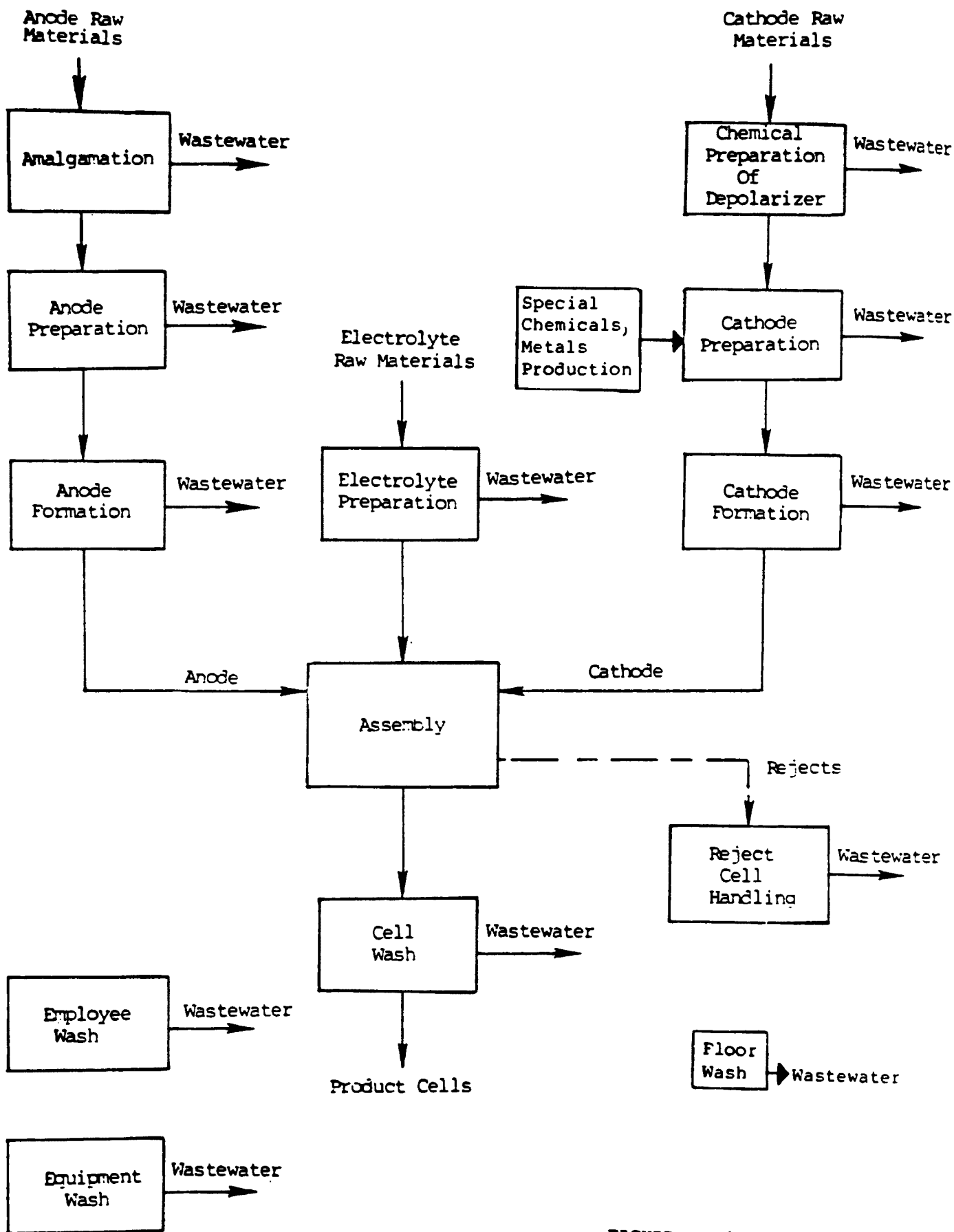
FIGURE V-2 4
GENERALIZED ZINC SUBCATEGORY MANUFACTURING
PROCESSES

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FIGURE V-25

ZINC SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources
Anode Manufacture	Cast or Fabricated	. No Process Wastewater
	Zinc Powder - Wet Amalgamated	. Floor Area and Equipment Clean-up . Spent Aqueous Solution . Amalgam Rinses . Reprocess Amalgam Rinses
	Zinc Powder - Gelled Amalgam	. Floor Area and Equipment Clean-up
	Zinc Powder - Dry Amalgamated	. No Process Wastewater
	Zinc Oxide Powder - Pasted or Pressed	. No Process Wastewater
	Zinc Oxide Powder - Pasted or Pressed, Reduced	. Post-formation Rinse
	Zinc Electrodeposited	. Post-electrodeposition Rinses . Spent Amalgamation Solution . Post-amalgamation Rinse
Cathode Manufacture	Porous Carbon	. No Process Wastewater
	Manganese Dioxide - Carbon	. No Process Wastewater
	Mercuric Oxide (and mercuric oxide - manganese dioxide carbon)	. No Process Wastewater
	Mercuric Oxide - Cadmium Oxide	. No Process Wastewater
	Silver Powder Pressed	. No Process Wastewater
	Silver Powder Pressed and Electrolytically Oxidized	. Post-formation Rinse

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FIGURE V-25 (CON'T)

ZINC SUBCATEGORY ANALYSIS

Grouping	Element	Specific Wastewater Sources
Cathode Manufacture (con't)	Silver Oxide (Ag_2O) Powder	. No Process Wastewater
	Silver Oxide (Ag_2O) Powder - Thermally Reduced or Sintered, Electrolytically Formed	. Slurry Paste Preparation . Spent Caustic Formation . Post-formation Rinse
	Silver Peroxide (AgO)	. Utensil Wash . Spent Solution . Product Rinse . Product Soak
	Nickel Impregnated	Refer to Cadmium Subcategory Analysis (Figure V-2)
Ancillary Operations	Cell Wash	. Acetic Acid Cell Wash . Chromic Acid Containing Cell Wash . Methylene Chloride Cell Wash . Freon Cell Wash . Non-chemical Cell Wash
	Electrolyte Preparation	. Equipment Wash
	Silver Etch	. Product Rinse
	Mandatory Employee Wash	. Employee Wash
	Reject Cell Handling	. Reject Cell Handling
	Floor Wash	. Floor Wash
	Equipment Wash	. Equipment Wash
	Silver Powder Production	. Product Rinse
	Silver Peroxide Production	. Product Rinses . Spent Solution

Zinc, Mercury
Solution → Mix

Water → Rinse → Rinse Wastewater Discharge

Methanol → Methanol Rinse → Contractor Removal Of Spent Methanol

Dry → Dry Powdered Amalgam → To Assembly
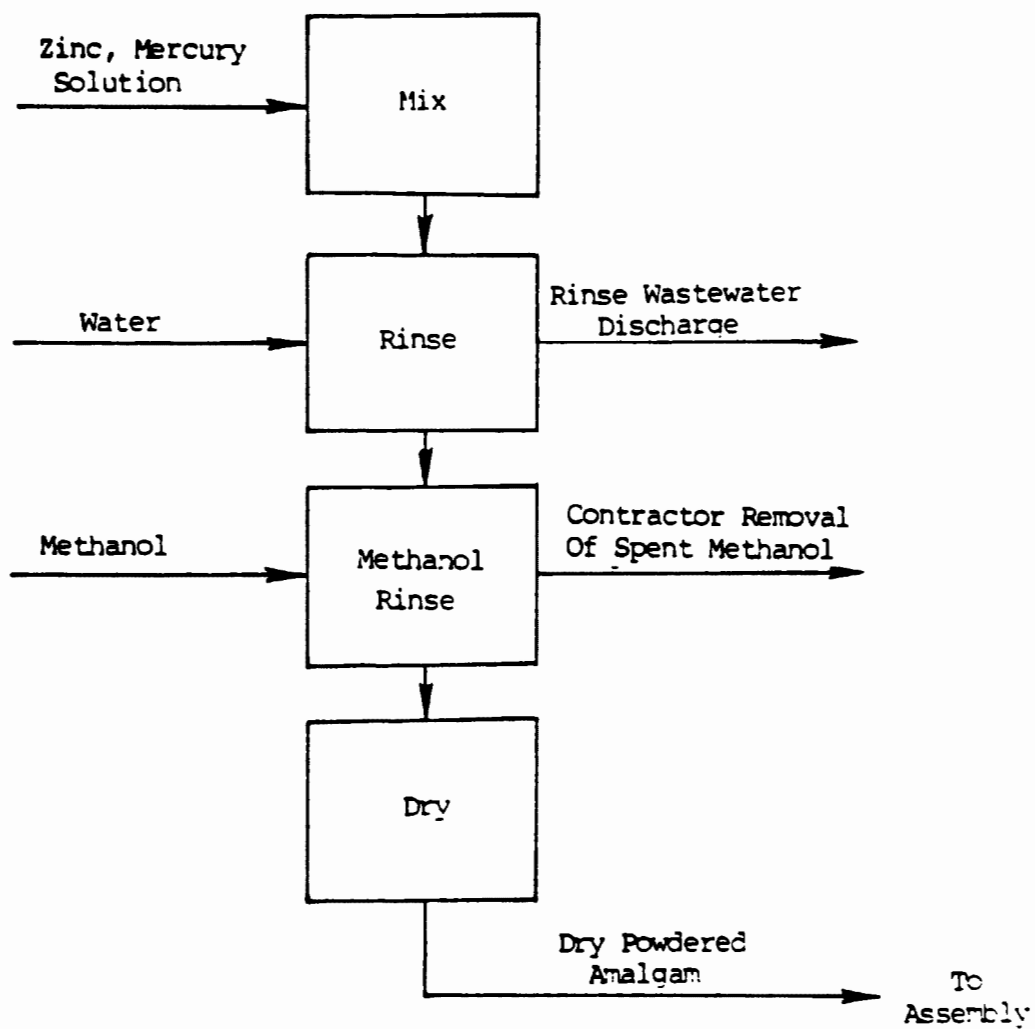
FIGURE V-26
PRODUCTION OF
ZINC POWDER - WET AMALGAMATED ANODES

219
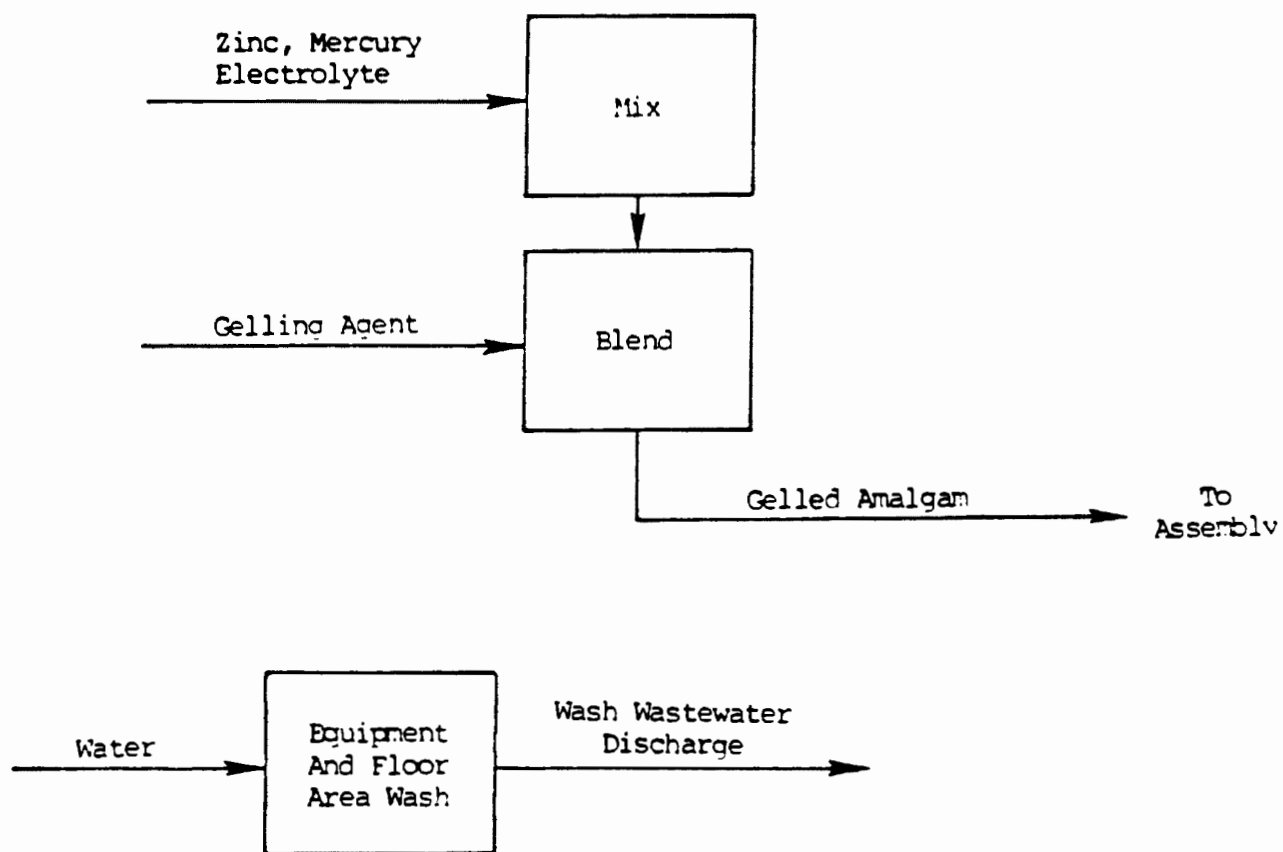
FIGURE V-27
PRODUCTION OF GELLED AMALGAM ANODES

220

Zinc Oxide And
Mercuric Oxide
Powders ────────────────► ┌──────────┐
                          │   Mix   │
                          └────┬─────┘
                               │
                               ▼
Binding Agent ────────────────► ┌──────────┐
                                │ Blend   │
                                └────┬─────┘
                                     │
                                     ▼
Grids ────────────────► ┌──────────┐
                        │ Press On │
                        │ Grids   │
                        └────┬─────┘
                             │
                             ▼
Caustic Solution ──────► ┌──────────┐
                         │ Electroly-│
                         │ tically │
                         │ Reduced │
                         └────┬─────┘
                              │
                              ▼
                                          Rinse Wastewater
                                             Discharge
Water ────────────────► ┌──────────┐ ──────────────────────►
                        │ Rinse   │
                        └────┬─────┘
                             │
                             ▼
                        ┌──────────┐
                        │   Dry   │
                        └────┬─────┘
                             │
                             │   Finished Anodes
                             └──────────────────────► To Assembly
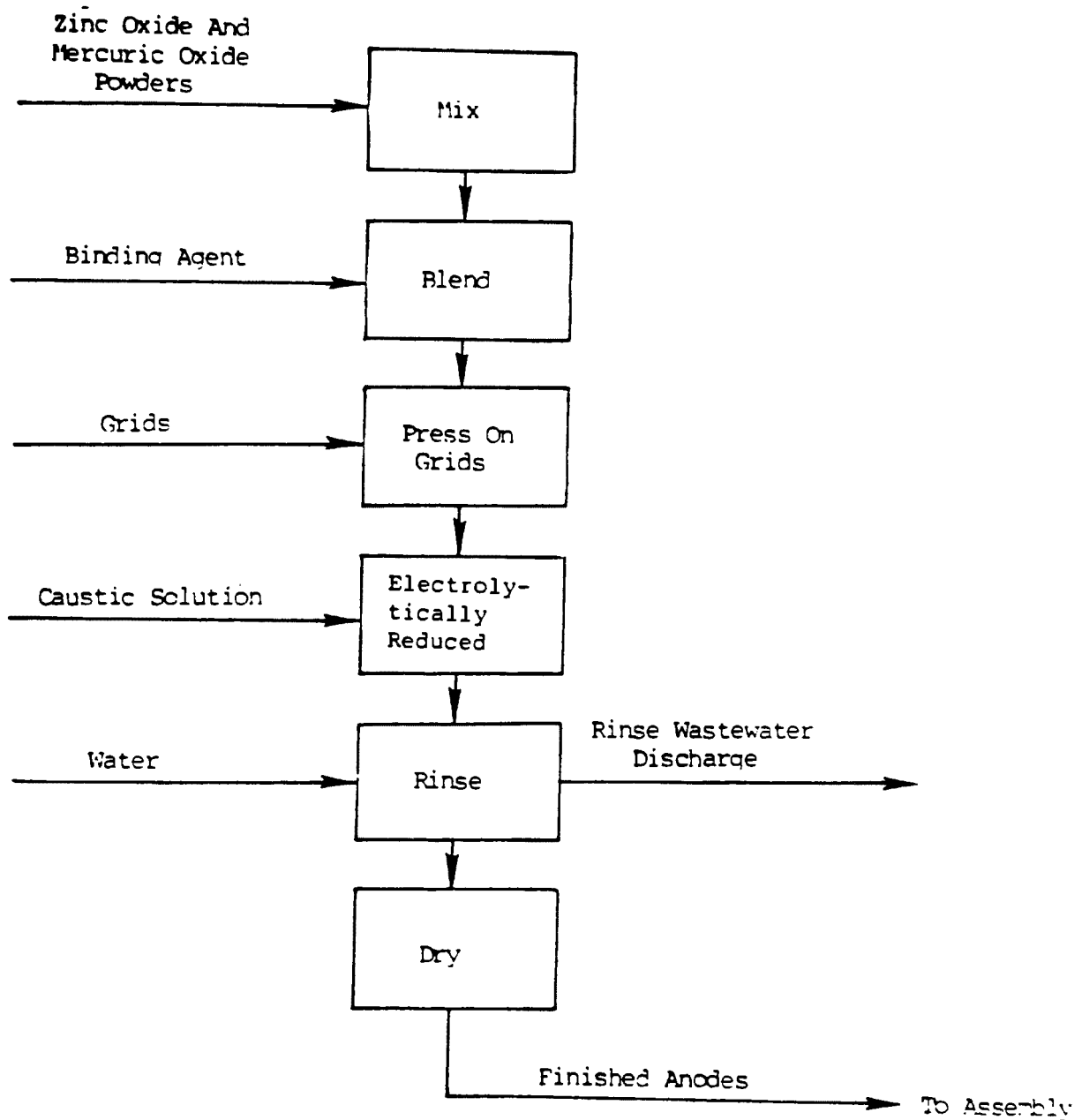
FIGURE V-28
PRODUCTION OF PRESSED ZINC OXIDE
ELECTROLYTICALLY REDUCED ANODES

221

Zinc Oxide, Mercuric Oxide Slurry → Mix

Binding Agent → Blend

Grids → Layer on Grids

Caustic Solution → Electrolytically reduced

Water → Rinse → Rinse Wastewater Discharge

Dry

Compress → Finished Anodes → To Assembly
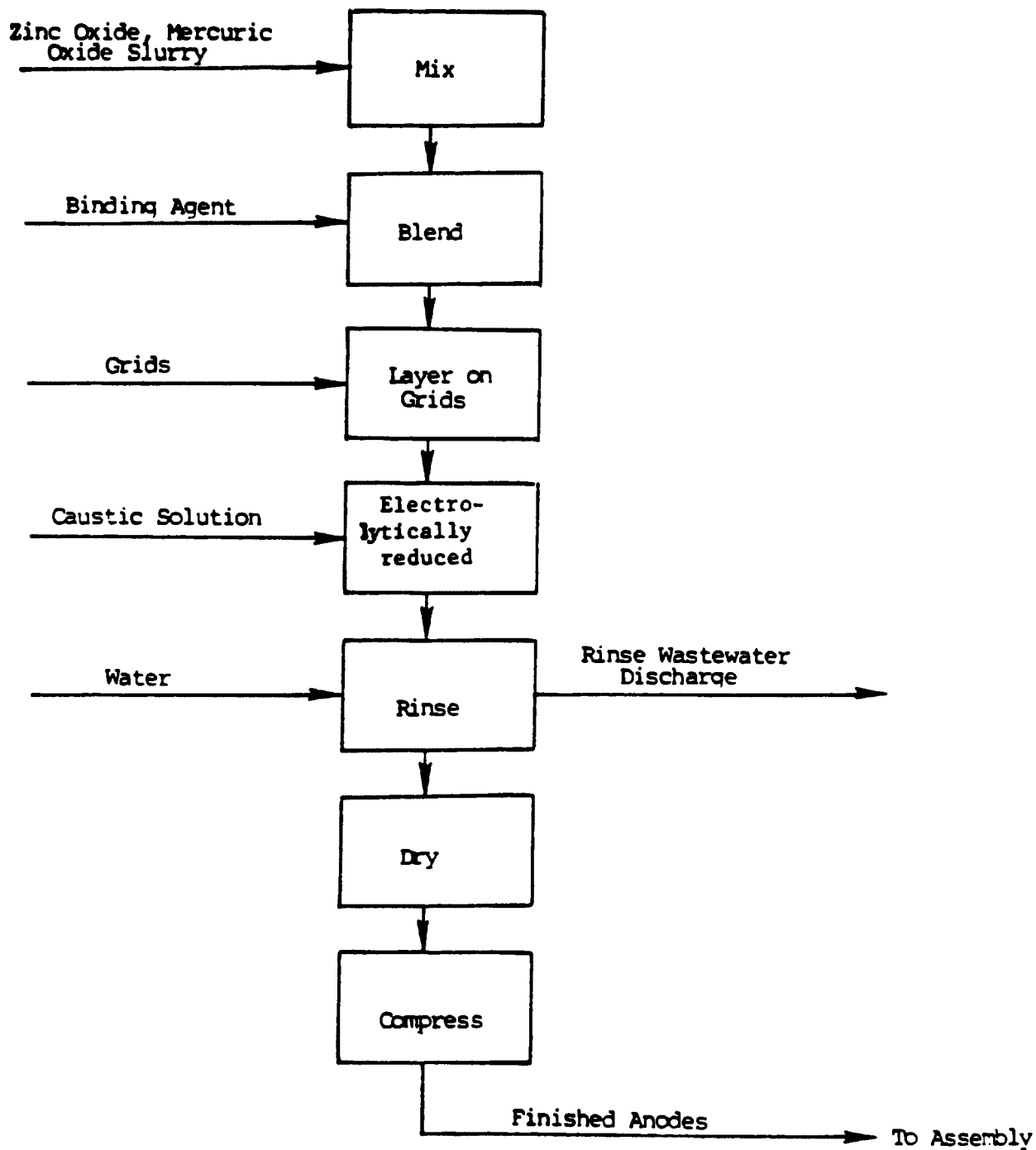
FIGURE V-29
PRODUCTION OF PASTED ZINC OXIDE
ELECTROLYTICALLY REDUCED ANODES

222
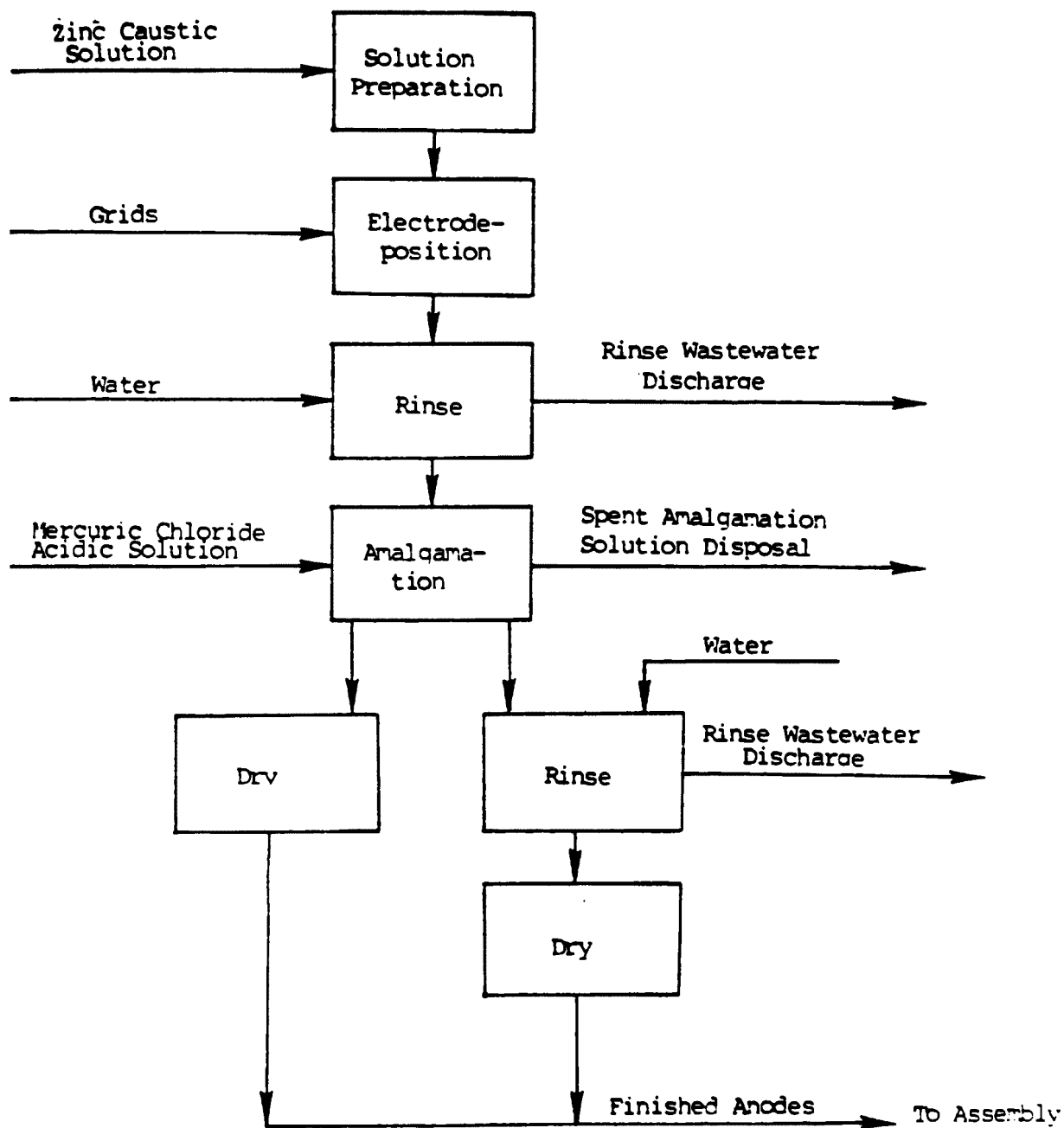
FIGURE V-30
PRODUCTION OF ELECTRODEPOSITED
ZINC ANODES

223
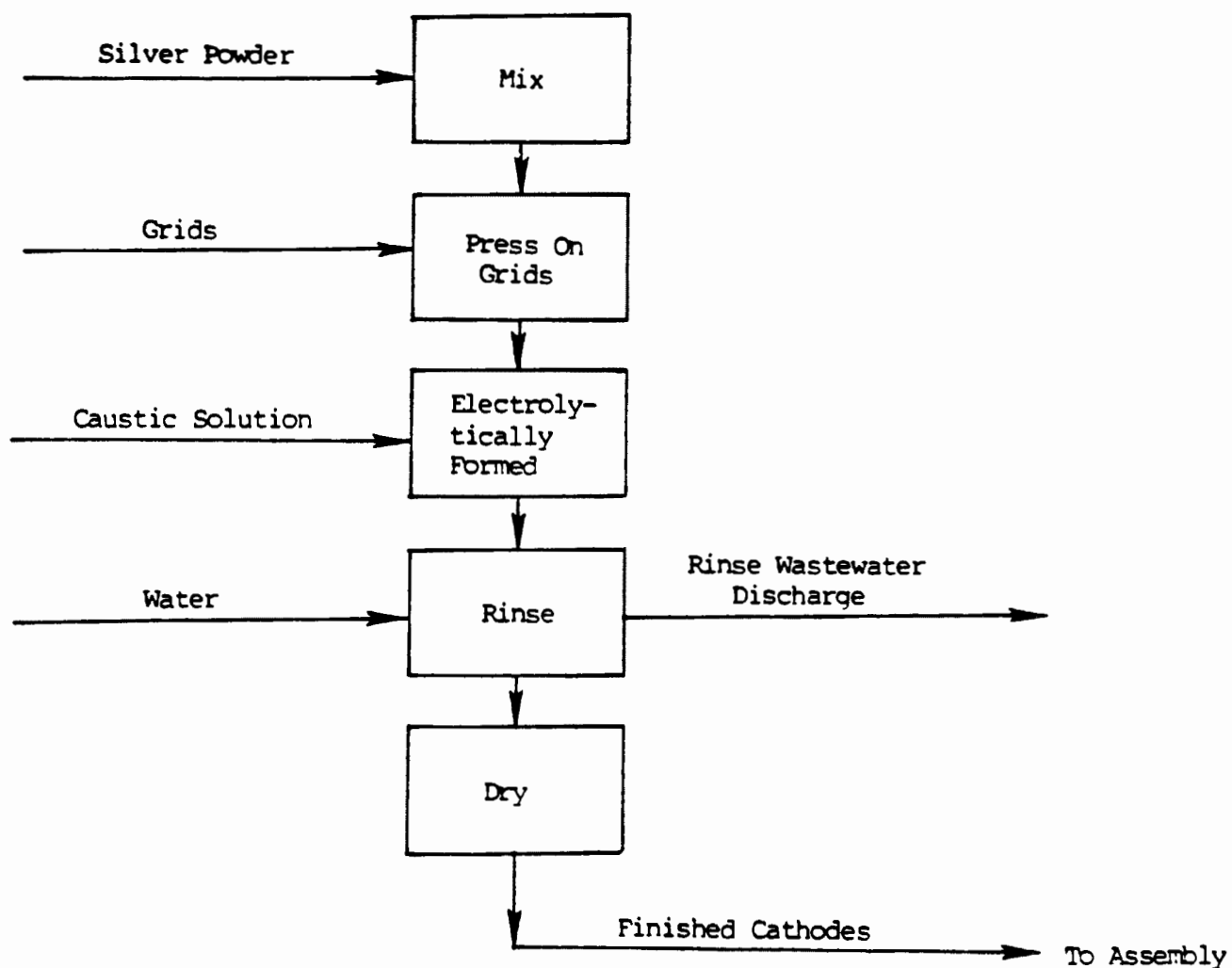
FIGURE V-3 1

PRODUCTION OF SILVER POWDER PRESSED
ELECTROLYTICALLY OXIDIZED CATHODES

224
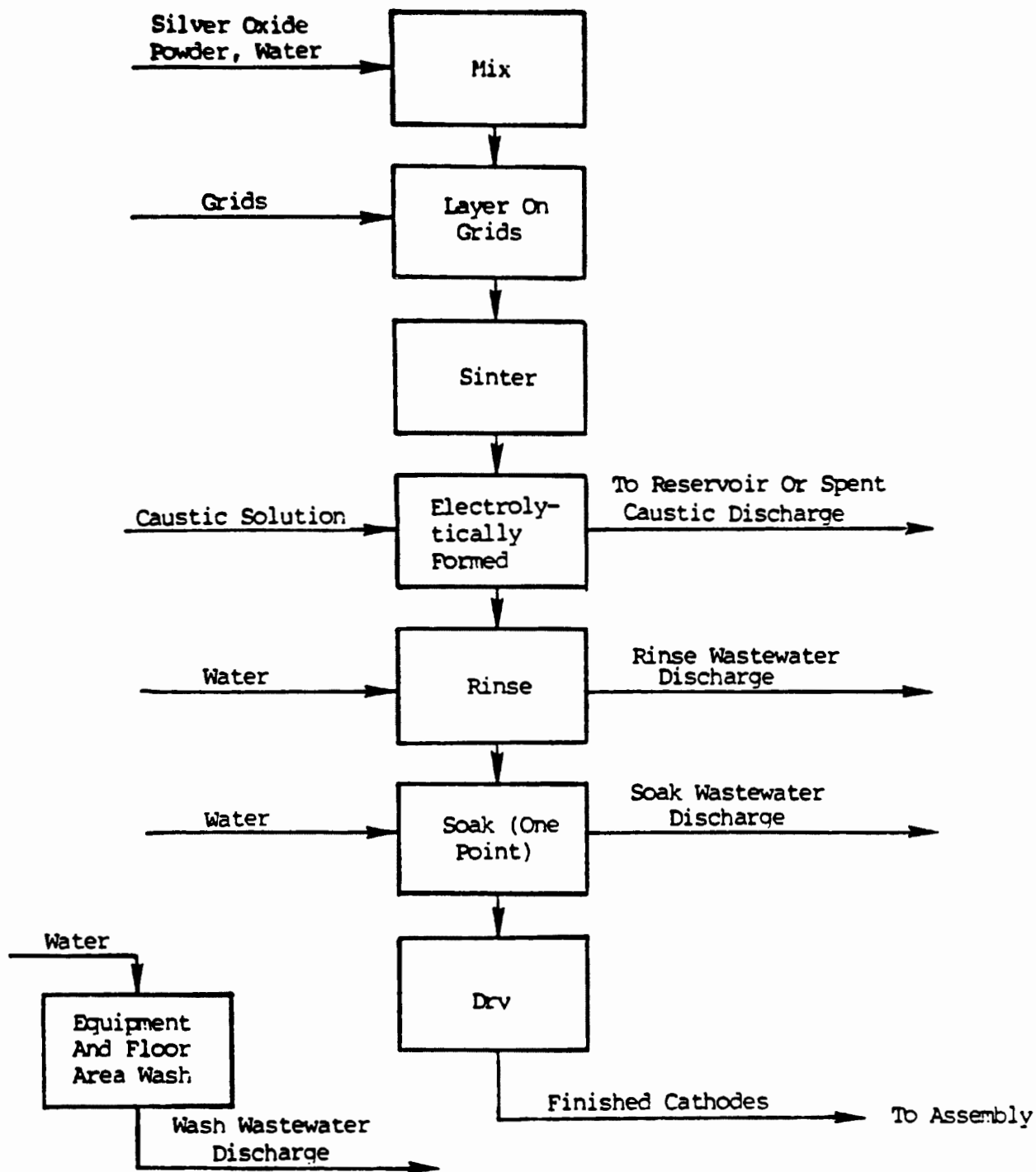
FIGURE V-3 2
PRODUCTION OF SILVER OXIDE (Ag$_2$O) POWDER
THERMALLY REDUCED OR SINTERED,
ELECTROLYTICALLY FORMED CATHODES

225

Silver Peroxide
Powder ────────▶ Pelletize

Solution ────────▶ Chemical
Treatment ────────▶ Spent Solution
Discharge ────────▶

Water ────────▶ Rinse ────────▶ Rinse Wastewater
Discharge ────────▶

Containers ────────▶ Dry And Place
In Container

Methanol-Hydrazine
Solution ────────▶ Chemical
Treatment ────────▶ Contractor Removal
Of Spent Solution ────────▶

Methanol ────────▶ Methanol
Rinse ────────▶ Contractor Removal
of Methanol ────────▶

Dry

Finished Cathodes ────────▶ To Assembly
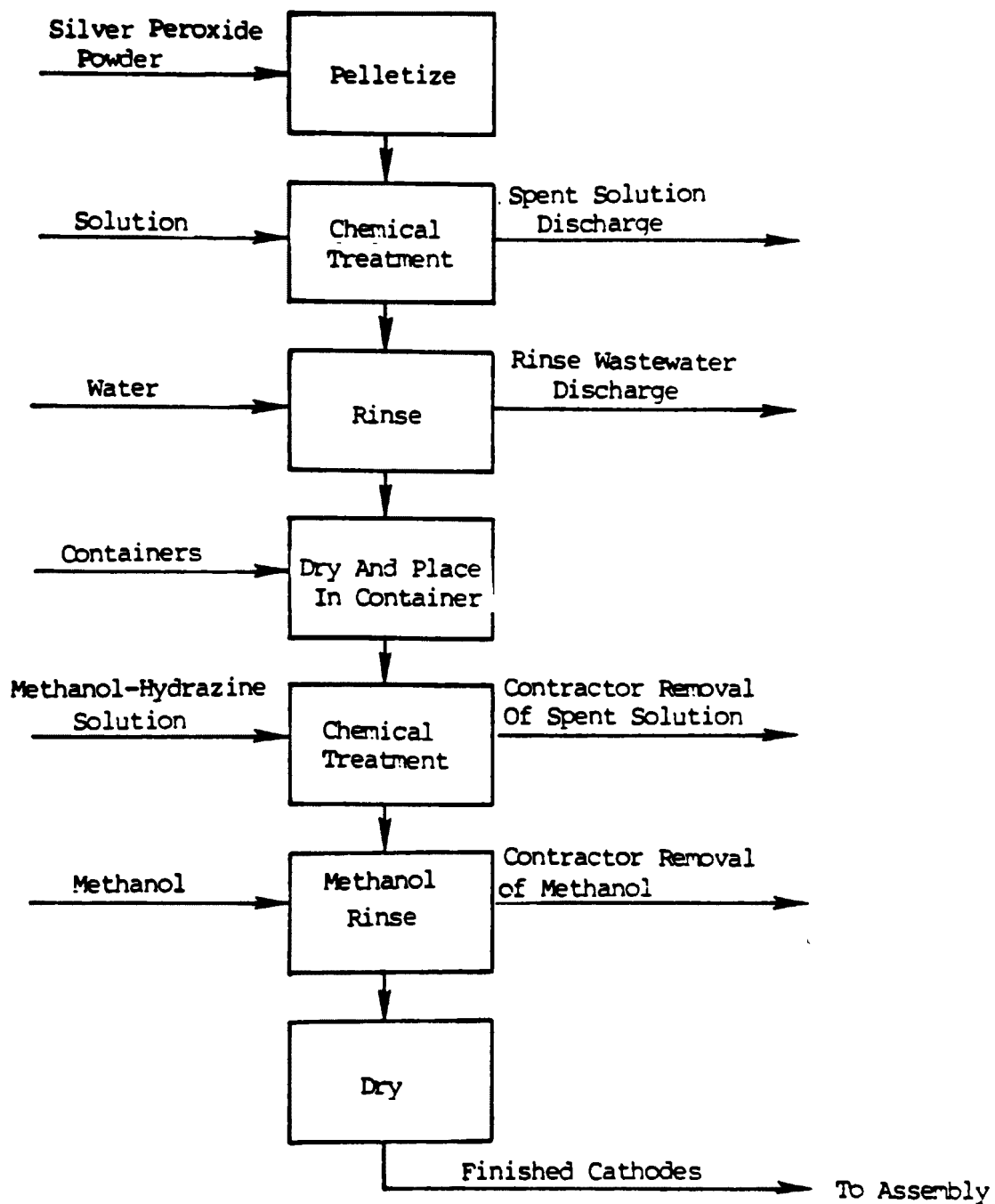
FIGURE V-3 3
CHEMICAL TREATMENT OF SILVER
PEROXIDE CATHODE PELLETS

226
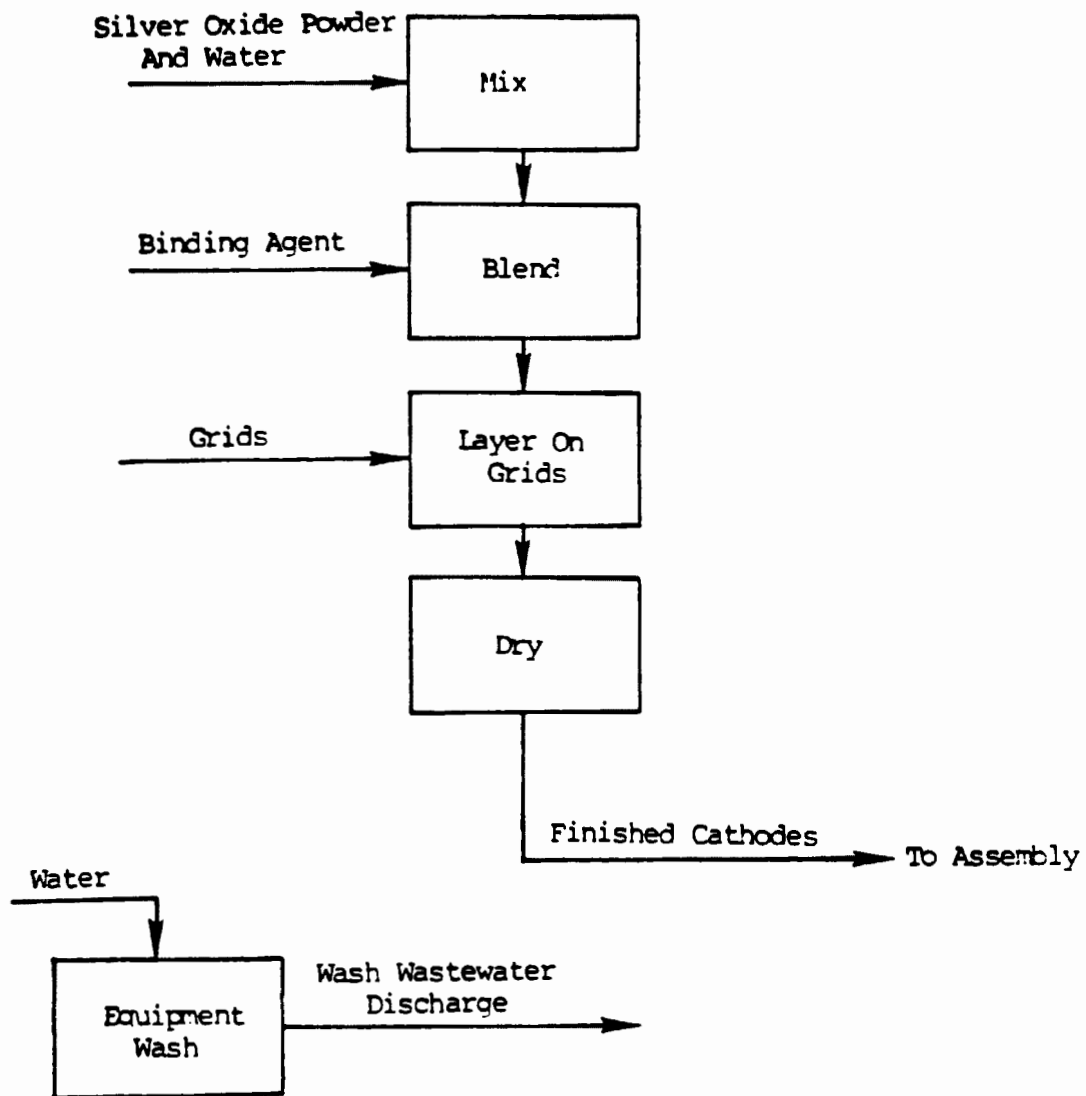
Figure V-34
PRODUCTION OF PASTED
SILVER PEROXIDE CATHODES

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TABLE V-1
SCREENING ANALYSIS RESULTS
CADMIUM SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
1.	Acenaphthene	ND	ND	ND	ND	ND
2.	Acrolein	ND	ND	ND	ND	ND
3.	Acrylonitrile	ND	ND	ND	ND	ND
4.	Benzene	ND	ND	ND	*	ND
5.	Benzidine	ND	ND	ND	ND	NA
6.	Carbon Tetrachloride	ND	ND	ND	ND	ND
7.	Chlorobenzene	ND	ND	ND	ND	ND
8.	1,2,4 Trichlorobenzene	ND	ND	ND	ND	NA
9.	Hexachlorobenzene	ND	ND	ND	ND	NA
10.	1, 2 Dichloroethane	ND	ND	ND	ND	ND
11.	1,1,1 Trichlorethane	ND	ND	ND	ND	ND
12.	Hexachloroethane	ND	ND	ND	ND	NA
13.	1,1 Dichloroethane	ND	ND	ND	ND	NA
14.	1,1,2 Trichloroethane	ND	ND	ND	ND	ND
15.	1,1,2,2 Tetrachloroethane	ND	ND	ND	ND	ND
16.	Chloroethane	ND	ND	ND	ND	ND
17.	Bis Chloromethyl Ether	ND	ND	ND	ND	ND
18.	Bis 2-Chloroethyl Ether	ND	ND	ND	ND	NA
19.	2-Chloroethyl Vinly Ether	ND	ND	ND	ND	ND
20.	2-Chloronaphthalene	ND	ND	ND	ND	NA
21.	2,4,6 Trichlorophenol	ND	ND	ND	ND	NA
22.	Parachlorometacresol	ND	ND	ND	ND	NA
23.	Chloroform	0.530	0.061	0.013	*	
24.	2 Chlorophenol	ND	ND	ND	ND	NA
25.	1,2 Dichlorobenzene	ND	ND	ND	ND	NA
26.	1,3 Dichlorobenzene	ND	ND	ND	ND	NA
27.	1,4 Dichlorobenzene	ND	ND	ND	ND	NA
28.	3,3 Dichlorobenzidine	ND	ND	ND	ND	NA
29.	1,1 Dichloroethylene	ND	ND	ND	ND	ND
30.	1,2 Trans-Dichloroethylene	ND	ND	ND	ND	ND
31.	2,4 Dichlorophenol	ND	ND	ND	ND	NA
32.	1,2 Dichloropropane	ND	ND	ND	ND	ND
33.	1,2 Dichloropropylene	ND	ND	ND	ND	ND
34.	2,4 Dimethylphenol	ND	ND	ND	ND	ND
35.	2,4 Dinitrotoluene	ND	ND	ND	ND	NA
36.	2,6 Dinitrotoluene	ND	ND	ND	ND	NA
37.	1,2 Diphenylhydrazine	ND	ND	ND	ND	NA
38.	Ethylbenzene	ND	ND	ND	ND	NA
39.	Fluoranthene	ND	ND	ND	ND	ND
40.	4 Chlorophenyl Phenyl Ether	ND	ND	ND	ND	NA
41.	4 Bromophenyl Phenyl Ether	ND	ND	ND	ND	NA
42.	Bis (2 Chloroisopropyl) Ether	ND	ND	ND	ND	NA
43.	Bis (2 Chloroethoxy) Methane	ND	ND	ND	ND	NA
44.	Methylene Chloride	0.024	0.027	0.61	0.044	
45.	Methyl Chloride	ND	ND	ND	ND	ND
46.	Methyl Bromide	ND	ND	ND	ND	ND
47.	Bromoform	ND	ND	ND	ND	ND
48.	Dichlorobromomethane	ND	ND	*	ND	ND
49.	Trichlorofluoromethane	ND	ND	ND	ND	ND
50.	Dichlorodifluoromethane	ND	ND	ND	ND	ND

TABLE V-1
SCREENING ANALYSIS RESULTS (CONT.)
CADMIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
51. Chlorodibromomethane		ND	ND	ND	ND
52. Hexachlorobutadiene		ND	ND	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	ND	NA
54. Isophorone		ND	ND	ND	NA
55. Naphthalene		ND	ND	ND	NA
56. Nitrobenzene		ND	ND	ND	NA
57. 2 Nitrophenol		ND	ND	ND	NA
58. 4 Nitrophenol		ND	ND	ND	NA
59. 2,4 Dinitrophenol		ND	ND	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	ND	NA
61. N-Nitrosodimethylamine		ND	ND	ND	NA
62. B-Nitrosodiphenylamine		ND	ND	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	ND	NA
64. Pentachlorophenol		ND	ND	ND	NA
65. Phenol	0,2	ND	ND	ND	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	*	*	NA
67. Butyl Benzyl Phthalate		ND	ND	ND	NA
68. Di-N-butyl Phthalate		ND	ND	ND	NA
69. Di-N-octyl Phthalate		ND	ND	ND	NA
70. Diethyl Phthalate		ND	ND	ND	NA
71. Dimethyl Phthalate		ND	ND	ND	NA
72. 1,2 Benzanthracene		ND	ND	ND	NA
73. Benzo (A) Pyrene		ND	ND	ND	NA
74. 3,4 Benzofluoranthene		ND	ND	ND	NA
75. 11, 12-Benzofluoranthene		ND	ND	ND	NA
76. Chrysene		ND	ND	ND	NA
77. Acenaphthylene		ND	ND	ND	NA
78. Anthracene		ND	ND	ND	NA
79. 1,12-Benzoperylene		ND	ND	ND	NA
80. Fluorene		ND	ND	ND	NA
81. Phenanthrene		ND	ND	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	ND	NA
83. Indenopyrene		ND	ND	ND	NA
84. Pyrene		ND	ND	ND	NA
85. Tetrachloroethylene		ND	ND	ND	ND
86. Toluene		ND	*	0.025	*
87. Trichloroethylene	0,1	ND	*	ND	ND
88. Vinyl Chloride		ND	ND	ND	ND
89. Aldrin		ND	ND	ND	NA
90. Dieldrin		ND	ND	ND	NA
91. Chlordane		ND	ND	ND	NA
92. 4,4 DDT		ND	ND	ND	NA
93. 4,4 DDE		ND	ND	ND	NA
94. 4,4 DDD		ND	ND	ND	NA
95. Alpha-Endosulfan		ND	ND	ND	NA
96. Beta-Endosulfan		ND	ND	ND	NA
97. Endosulfan Sulfate		ND	ND	ND	NA
98. Endrin		ND	ND	ND	NA
99. Endrin Aldehyde		ND	ND	ND	NA
100. Heptachlor		ND	ND	ND	NA

TABLE V-1
SCREENING ANALYSIS RESULTS (CONT.)
CADMIUM SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
101. Heptachlor Epoxide		ND	ND	ND	NA
102. Alpha-BHC		ND	ND	ND	NA
103. Beta-BHC		ND	ND	ND	NA
104. Gamma-BHC (Lindane)		ND	ND	ND	NA
105. Delta-BHC		ND	ND	ND	NA
106. PCB-1242		ND	ND	ND	NA
107. PCB-1254		ND	ND	ND	NA
108. PCB-1221		ND	ND	ND	NA
109. PCB-1232		ND	ND	ND	NA
110. PCB-1248		ND	ND	ND	NA
111. PCB-1260		ND	ND	ND	NA
112. PCB-1016		ND	ND	ND	NA
113. Toxaphene		ND	ND	ND	NA
114. Antimony	1,0	ND	ND	ND	NA
115. Arsenic	1,0	ND	ND	ND	NA
116. Asbestos		NA	NA	NA	NA
117. Beryllium		< 0.001	< 0.01	< 0.01	NA
118. Cadmium	4,0	0.009	70	100	NA
119. Chromium	2,0	0.007	.08	< 0.05	NA
120. Copper		0.010	< 0.09	< 0.09	NA
121. Cyanide	1,0	0.020	0.07	0.04	NA
122. Lead		0.020	0.40	0.40	NA
123. Mercury		0.0003	0.0003	0.0003	NA
124. Nickel	7,0	< 0.005	100	70	NA
125. Selenium		ND	ND	ND	NA
126. Silver		< 0.0001	< 0.01	< 0.01	NA
127. Thallium		ND	ND	ND	NA
128. Zinc		0.090	< 0.5	< 0.5	NA
129. 2,3,7,8 TCDD (Dioxin)		NA	NA	NA	NA
130. Xylenes		NA	NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA	NA
Aluminum	-,-	< 0.090	< 0.90	< 0.90	NA
Ammonia	-,-	0.12	5.76	3.57	NA
Barium	-,-	0.020	< 0.06	< 0.06	NA
Boron	-,-	< 0.080	< 0.80	< 0.80	NA
Calcium	-,-	18.0	< 50	< 50	NA
Cobalt	-,-	< 0.002	< 0.02	< 0.02	NA
Fluoride	-,-	1.20	1.15	1.15	NA
Gold	-,-	< 0.001	ND	ND	NA
Iron	-,-	< 0.1	1.00	< 1	NA
Magnesium	-,-	7.8	7.00	7.00	NA
Manganese	-,-	0.03	0.10	0.09	NA
Molybdenum	-,-	< 0.006	< 0.06	< 0.06	NA
Oil and Grease	-,-	6.0	< 5.00	< 5.00	NA
Phenols (Total)	-,-	< 0.005	< 0.009	< 0.009	NA
Phosphorus	-,-	ND	0.05	ND	NA
Sodium	-,-	8.8	400	510	NA
Strontium	-,-	NA	NA	NA	NA
TSS	-,-	< 5.0	368	338	NA
Tin	-,-	0.05	0.30	< 0.08	NA
Titanium	-,-	< 0.006	< 0.06	< 0.06	NA
Vanadium	-,-	< 0.002	< 0.02	< 0.02	NA
Yttrium	-,-	< 0.002	< 0.02	< 0.02	NA

TABLE V-1
SCREENING ANALYSIS RESULTS (CONT.)
CADMIUM SUBCATEGORY

DCP Data KTBP, BTBP	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Effluent Conc. mg/1	Analysis Blank Conc. mg/1

ND   Not detected

NA   Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis were not finalized for these parameters).

KTBP   Known to be present indicated by number of plants.

BTBP   Believed to be present indicated by number of plants.

-,-   Not investigated in DCP survey.

*   Indicates less than .01 mg/1.

**   Indicates less than .005 mg/1.

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TABLE V-2
SCREENING ANALYSIS RESULTS

CALCIUM SUBCATEGORY

		Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
	DPC Data KTBP, BTBP			
1.	Acenaphthene	ND	ND	NA
2.	Acrolein	ND	ND	ND
3.	Acrylontirile	ND	ND	ND
4.	Benzene	ND	ND	ND
5.	Benzidine	ND	ND	NA
6.	Carbon Tetrachloride	ND	ND	ND
7.	Chlorobenzene	ND	ND	ND
8.	1,2,4 Trichlorobenzene	ND	ND	NA
9.	Hexachlorobenzene	ND	ND	NA
10.	1,2 Dichloroethane	ND	ND	ND
11.	1,1,1 Trichloroethane	ND	ND	ND
12.	Hexachloroethane	ND	ND	NA
13.	1,1 Dichloroethane	ND	ND	ND
14.	1,1,2 Trichloroethane	ND	0.013	ND
15.	1,1,2,2 Tetrachloroethane	ND	ND	ND
16.	Chloroethane	ND	ND	ND
17.	Bis Chloromethyl Ether	ND	ND	ND
18.	Bis 2-Chloroethyl Ether	ND	ND	NA
19.	2-Chloroethyl Vinyl Ether	ND	ND	ND
20.	2-Chloronapthalene	ND	ND	NA
21.	2,4,6 Trichlorophenol	ND	ND	NA
22.	Parachlorometacresol	ND	ND	NA
23.	Chloroform	0.055	0.038	*
24.	2 Chlorophenol	ND	ND	NA
25.	1,2 Dichlorobenzene	ND'	ND	NA
26.	1,3 Dichlorobenzene	ND	ND	NA
27.	1,4 Dichlorobenzene	ND	ND	NA
28.	3,3 Dichlorobenzidine	ND	ND	NA
29.	1,1 Dichloroethylene	ND	ND	ND
30.	1,2 Trans-Dichloroethylene	ND	ND	ND
31.	2,4 Dichlorophenol	ND	ND	NA
32.	1,2 Dichloropropane	ND	ND	ND
33.	1,2 Dichloropropylene	ND	ND	ND
34.	2,4 Dimethylphenol	ND	ND	NA
35.	2,4 Dinitrotoluene	ND	ND	NA
36.	2,6 Dinitrotoluene	ND	ND	NA
37.	1,2 Diphenylhydrazine	ND	ND	NA
38.	Ethylbenzene	ND	ND	ND
39.	Fluoranthene	ND	ND	NA
40.	4 Chlorophenyl Phenyl Ether	ND	ND	NA

TABLE V-2

SCREENING ANALYSIS RESULTS (CONT.)

CALCIUM SUBCATEGORY

DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
41. 4 Bromophenyl Phenyl Ether	ND	ND	NA
42. Bis (2 Chloroisopropyl) Ether	ND	ND	NA
43. Bis (2 Chloroethoxy) Methane	ND	ND	NA
44. Methylene Chloride	0.011	0.014	*
45. Methyl Chloride	ND	ND	ND
46. Methyl Bromide	ND	ND	ND
47. Bromoform	ND	ND	ND
48. Dichlorobromomethane	ND	ND	ND
49. Trichlorofluoromethane	ND	ND	ND
50. Dichlorodifluoromethane	ND	ND	ND
51. Chlorodibromomethane	ND	ND	ND
52. Hexachlorobutadiene	ND	ND	NA
53. Hexachlorocyclopentadiene	ND	ND	NA
54. Isophorone	ND	ND	NA
55. Naphthalene	ND	ND	NA
56. Nitrobenzene	ND	ND	NA
57. 2 Nitrophenol	ND	ND	NA
58. 4 Nitrophenol	ND	ND	NA
59. 2,4 Dinitrophenol	ND	ND	NA
60. 4,6 Dinitro-o-cresol	ND	ND	NA
61. N-Nitrosodimethylamine	ND	ND	NA
62. N-Nitrosodiphenylamine	ND	ND	NA
63. N-Nitrosodi-N-propylamine	ND	ND	NA
64. Pentachlorophenol	*	*	NA
65. Phenol	ND	ND	NA
66. Bis (2-Ethylhexyl) Phthalate	ND	0.024	NA
67. Butyl Benzyl Phthalate	ND	ND	NA
68. Di-N-butyl Phthalate	*	*	NA
69. Di-N-octyl Phthalate	ND	ND	NA
70. Diethyl Phthalate	ND	ND	NA
71. Dimethyl Phthalate	ND	ND	NA
72. 1,2 Benzanthracene	ND	ND	NA
73. Benzo (A) Pyrene	ND	ND	NA
74. 3,4 Benzofluorathene	ND	ND	NA
75. 11, 12-Benzofluoranthene	ND	ND	NA
76. Chrysene	ND	ND	NA
77. Acenaphthylene	ND	ND	NA
78. Anthracene	ND	ND	NA
79. 1,12-Benzoperylene	ND	ND	NA
80. Fluorene	ND	ND	NA

TABLE V-2
SCREENING ANALYSIS RESULTS (CONT.)

CALCIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
81. Phenanthrene		ND	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	NA
83. Indenopyrene		ND	ND	NA
84. Pyrene		ND	ND	NA
85. Tetrachloroethylene		ND	ND	ND
86. Toluene		ND	*	ND
87. Trichloroethylene		ND	ND	ND
88. Vinyl Chloride		ND	ND	ND
89. Aldrin		ND	ND	NA
90. Dieldrin		ND	ND	NA
91. Chlordane		ND	ND	NA
92. 4,4 DDT		ND	ND	NA
93. 4,4 DDE		ND	ND	NA
94. 4,4 DDD		ND	ND	NA
95. Alpha-Endosulfan		ND	ND	NA
96. Beta-Endosulfan		ND	ND	NA
97. Endosulfan Sulfate		ND	ND	NA
98. Endrin		ND	ND	NA
99. Endrin Aldehyde		ND	ND	NA
100. Heptachlor		ND	ND	NA
101. Heptachlor Epoxide		ND	ND	NA
102. Alpha-BHC		ND	ND	NA
103. Beta-BHC		ND	ND	NA
104. Gamma-BHC (Lindane)		ND	ND	NA
105. Delta-BHC		ND	ND	NA
106. PCB-1242		ND	ND	NA
107. PCB-1254		ND	ND	NA
108. PCB-1221		ND	ND	NA
109. PCB=1232		ND	ND	NA
110. PCB-1248		ND	ND	NA
111. PCB-1260		ND	ND	NA
112. PCB-1016		ND	ND	NA
113. Toxaphene		ND	ND	NA
114. Antimony		<0.005	<0.005	NA
115. Arsenic		<0.005	<0.005	NA
116. Asbestos				NA
117. Beryllium		<0.001	<0.001	NA
118. Cadmium	0,1	0.001	0.001	NA
119. Chromium	0,2	0.005	2.06	NA
120. Copper		0.068	0.118	NA

TABLE V-2
SCREENING ANALYSIS RESULTS (CONT.)

CALCIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
121. Cyanide		ND	ND	NA
122. Lead		0.025	0.044	NA
123. Mercury		<0.001	<0.001	NA
124. Nickel		0.060	0.067	NA
125. Selenium		<0.005	<0.005	NA
126. Silver		0.003	0.012	NA
127. Thallium		<0.050	<0.050	NA
128. Zinc		0.018	0.045	NA
129. 2,3,7,8 TCDD (Dioxin)		ND	ND	NA
130. Xylenes		NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA
Aluminum	-,-	0.086	0.104	NA
Ammonia	-,-	NA	NA	NA
Barium	-,-	0.016	2.67	NA
Boron	-,-	0.040	0.116	NA
Calcium	-,-	15.4	15.9	NA
Cobalt	-,-	0.011	0.006	NA
Fluoride	-,-	1.7	1.7	NA
Gold	-,-	NA	NA	NA
Iron	-,-	0.091	0.122	NA
Magnesium	-,-	3.47	3.66	NA
Manganese	-,-	0.007	0.008	NA
Molybdenum	-,-	<0.001	0.001	NA
Oil and Grease	-,-	ND	ND	NA
Phenols (Total)	-,-	ND	ND	NA
Phosphorus	-,-	ND	ND	NA
Sodium	-,-	5.73	6.06	NA
Strontium	-,-	NA	NA	NA
TSS	-,-	ND	21	NA
Tin	-,-	0.012	0.006	NA
Titanium	-,-	0.001	0.001	NA
Vanadium	-,-	0.030	0.030	NA
Yttrium	-,-	<0.001	0.001	NA

TABLE V-2
SCREENING ANALYSIS RESULTS (CONT.)

CALCIUM SUBCATEGORY

DPC Data KTBP, BTBP	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Analysis Blank Conc. mg/1

ND   Not detected

NA   Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis
         were not finalized for these parameters).

KTBP Known to be present indicated by number of plants.

BTBP Believed to be present indicated by number of plants.

-,-   Not investigated in DCP survey.

 *   Indicates less than 0.01 mg/1.

**   Indicates less than 0.005 mg/1.

TABLE V-3
SCREENING ANALYSIS RESULTS
LEAD SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Effluent Conc. mg/1	Analysis Blank Conc. mg/1
1.	Acenaphthene		ND	*	ND	NA
2.	Acrolein		ND	ND	ND	NA
3.	Acrylonitrile		ND	ND	ND	NA
4.	Benzene		*	*	*	NA
5.	Benzidine		ND	ND	ND	*
6.	Carbon Tetrachloride		ND	ND	ND	ND
7.	Chlorobenzene		ND	ND	ND	ND
8.	1,2,4 Trichlorobenzene		ND	ND	ND	NA
9.	Hexachlorobenzene		ND	ND	ND	NA
10.	1, 2 Dichloroethane	0,1	ND	ND	ND	ND
11.	1,1,1 Trichlorethane	0,5	*	0.025	*	ND
12.	Hexachloroethane		ND	ND	ND	NA
13.	1,1 Dichloroethane		ND	ND	ND	ND
14.	1,1,2 Trichloroethane		ND	ND	ND	ND
15.	1,1,2,2 Tetrachloroethane		ND	ND	ND	ND
16.	Chloroethane		ND	ND	ND	ND
17.	Bis Chloromethyl Ether		ND	ND	ND	ND
18.	Bis 2-Chloroethyl Ether		ND	ND	ND	NA
19.	2-Chloroethyl Vinyl Ether		ND	ND	ND	ND
20.	2-Chloronaphthalene		ND	ND	ND	NA
21.	2,4,6 Trichlorophenol		ND	ND	*	NA
22.	Parachlorometacresol		ND	ND	ND	NA
23.	Chloroform		0.06	*	0.029	*
24.	2 Chlorophenol		ND	*	*	NA
25.	1,2 Dichlorobenzene		ND	ND	ND	NA
26.	1,3 Dichlorobenzene		ND	*	ND	NA
27.	1,4 Dichlorobenzene		ND	ND	ND	NA
28.	3,3 Dichlorobenzidine		ND	ND	ND	NA
29.	1,1 Dichloroethylene		ND	ND	ND	ND
30.	1,2 Trans-Dichloroethylene		ND	ND	ND	ND
31.	2,4 Dichlorophenol		ND	*	*	NA
32.	1,2 Dichloropropane		ND	ND	ND	ND
33.	1,2 Dichloropropylene		ND	ND	ND	ND
34.	2,4 Dimethylphenol		ND	ND	ND	NA
35.	2,4 Dinitrotoluene		ND	ND	ND	NA
36.	2,6 Dinitrotoluene		ND	ND	ND	NA
37.	1,2 Diphenylhydrazine		ND	ND	ND	NA
38.	Ethylbenzene		ND	*	*	ND
39.	Fluoranthene		ND	*	*	NA
40.	4 Chlorophenyl Phenyl Ether		ND	ND	ND	NA
41.	4 Bromophenyl Phenyl Ether		ND	ND	ND	NA
42.	Bis (2 Chloroisopropyl) Ether		ND	ND	ND	NA
43.	Bis (2 Chloroethoxy) Methane		ND	ND	ND	NA
44.	Methylene Chloride	6,0	0.017	*	*	0.012
45.	Methyl Chloride		ND	ND	ND	ND
46.	Methyl Bromide		ND	ND	ND	ND
47.	Bromoform		ND	ND	ND	ND
48.	Dichlorobromomethane		*	*	*	ND
49.	Trichlorofluoromethane		ND	ND	ND	ND
50.	Dichlorodifluoromethane	0,4	ND	ND	ND	ND

TABLE V-3
SCREENING ANALYSIS RESULTS (CONT.)
LEAD SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
51. Chlorodibromomethane		*	*	ND	ND
52. Hexachlorobutadiene		ND	ND	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	ND	NA
54. Isophorone		ND	ND	ND	NA
55. Naphthalene	0,6	ND	*	ND	NA
56. Nitrobenzene		ND	ND	ND	NA
57. 2 Nitrophenol		ND	ND	ND	NA
58. 4 Nitrophenol		ND	ND	ND	NA
59. 2,4 Dinitrophenol		ND	ND	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	ND	NA
61. N-Nitrosodimethylamine		ND	ND	ND	NA
62. B-Nitrosodiphenylamine		ND	ND	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	ND	NA
64. Pentachlorophenol		ND	ND	ND	NA
65. Phenol		*	*	*	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	0.135	0.016	NA
67. Butyl Benzyl Phthalate		ND	0.017	ND	NA
68. Di-N-butyl Phthalate		ND	*	*	NA
69. Di-N-octyl Phthalate		ND	0.140	ND	NA
70. Diethyl Phthalate		ND	ND	ND	NA
71. Dimethyl Phthalate		ND	ND	ND	NA
72. 1,2 Benzanthracene		ND	*	*	NA
73. Benzo (A) Pyrene		ND	*	ND	NA
74. 3,4 Benzofluoranthene		ND	*	ND	NA
75. 11, 12-Benzofluoranthene		ND	*	ND	NA
76. Chrysene		ND	*	*	NA
77. Acenaphthylene		ND	ND	ND	NA
78. Anthracene		ND	0.032	0.007	NA
79. 1,12-Benzoperylene		ND	ND	ND	NA
80. Fluorene		ND	*	ND	NA
81. Phenanthrene		ND	0.032	0.007	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	ND	NA
83. Indenopyrene		ND	ND	ND	NA
84. Pyrene		ND	*	*	NA
85. Tetrachloroethylene		ND	ND	ND	ND
86. Toluene	0,1	*	*	*	*
87. Trichloroethylene		*	*	*	*
88. Vinyl Chloride		ND	ND	ND	ND
89. Aldrin		ND	ND	ND	NA
90. Dieldrin		ND	ND	ND	NA
91. Chlordane		ND	ND	ND	NA
92. 4,4 DDT		ND	ND	ND	NA
93. 4,4 DDE		ND	ND	ND	NA
94. 4,4 DDD		ND	ND	ND	NA
95. Alpha-Endosulfan		ND	ND	ND	NA
96. Beta-Endosulfan		ND	ND	ND	NA
97. Endosulfan Sulfate		ND	ND	ND	NA
98. Endrin		ND	ND	ND	NA
99. Endrin Aldehyde		ND	ND	ND	NA
100. Heptachlor		ND	ND	ND	NA

TABLE V-3
SCREENING ANALYSIS RESULTS (CONT.)
LEAD SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Effluent Conc. mg/1	Analysis Blank Conc. mg/1
101. Heptachlor Epoxide		ND	**	ND	NA
102. Alpha-BHC		ND	ND	ND	NA
103. Beta-BHC		ND	ND	ND	NA
104. Gamma-BHC (Lindane)		ND	ND	ND	NA
105. Delta-BHC		ND	ND	ND	NA
106. PCB-1242	0,1	ND	ND	ND	NA
107. PCB-1254	0,1	ND	ND	ND	NA
108. PCB-1221		ND	ND	ND	NA
109. PCB-1232		ND	ND	ND	NA
110. PCB-1248		ND	ND	ND	NA
111. PCB-1260	0,1	ND	ND	ND	NA
112. PCB-1016		ND	ND	ND	NA
113. Toxaphene		ND	ND	ND	NA
114. Antimony	38,8	< 0.1	< 0.1	< 0.1	NA
115. Arsenic	30,7	ND	ND	ND	NA
116. Asbestos		ND	ND	ND	NA
117. Beryllium		< 0.001	< 0.001	< 0.001	NA
118. Cadmium	24,2	0.010	< 0.01	< 0.002	NA
119. Chromium	15,2	0.009	0.01	< 0.005	NA
120. Copper	14,32	0.040	0.09	< 0.006	NA
121. Cyanide		ND	< 0.005	< 0.005	NA
122. Lead	65,9	0.200	14.0	2.0	NA
123. Mercury	0,6	NA	NA	NA	NA
124. Nickel	20,8	0.010	< 0.005	< 0.005	NA
125. Selenium	6,0	ND	ND	ND	NA
126. Silver	6,5	< 0.001	.033	ND	NA
127. Thallium		ND	ND	ND	NA
128. Zinc	21,7	0.300	0.40	0.10	NA
129. 2,3,7,8 TCDD (Dioxin)		NA	NA	NA	NA
130. Xylenes	0,3	NA	NA	NA	NA
131. Alkyl Epoxides	0,2	NA	NA	NA	NA
Aluminum	-,-	0.060	0.20	< 0.05	NA
Ammonia	-,-	NA	NA	NA	NA
Barium	-,-	0.007	0.03	< 0.005	NA
Boron	-,-	NA	NA	NA	NA
Calcium	-,-	11.000	26.0	45.0	NA
Cobalt	-,-	< 0.005	< 0.005	< 0.005	NA
Fluoride	-,-	0.820	0.8	.92	NA
Gold	-,-	ND	ND	ND	NA
Iron	-,-	< 0.2	2.00	< 0.2	NA
Magnesium	-,-	1.800	2.20	2.10	NA
Manganese	-,-	0.090	0.06	0.03	NA
Molybdenum	-,-	0.020	0.008	< 0.005	NA
Oil and Grease	-,-	7.30	36.5	10.0	NA
Phenols (Total)	-,-	ND	0.008	< 0.005	NA
Phosphorus	-,-	0.040	0.58	0.04	NA
Sodium	-,-	< 0.015	100	260	NA
Strontium	-,-	NA	NA	NA	NA
TSS	-,-	ND	57.8	90.6	NA
Tin	-,-	0.060	0.02	< 0.005	NA
Titanium	-,-	0.040	< 0.02	< 0.02	NA
Vanadium	-,-	< 0.01	< 0.01	< 0.01	NA
Yttrium	-,-	< 0.02	< 0.02	< 0.02	NA

TABLE V-3
SCREENING ANALYSIS RESULTS (CONT.)
LEAD SUBCATEGORY

DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l

ND   Not detected

NA   Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis were not finalized for these parameters).

KTBP   Known to be present indicated by number of plants.

BTBP   Believed to be present indicated by number of plants.

-,-   Not investigated in DCP survey.

*   Indicates less than .01 mg/l.

**   Indicates less than .005 mg/l.

TABLE V-4
SCREENING ANALYSIS RESULTS
LECLANCHE SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
1.	Acenaphthene		ND	ND	ND
2.	Acrolein		ND	ND	NA
3.	Acrylonitrile		ND	ND	ND
4.	Benzene		ND	ND	ND
5.	Benzidine		ND	ND	NA
6.	Carbon Tetrachloride		ND	ND	ND
7.	Chlorobenzene		ND	ND	NA
8.	1,2,4 Trichlorobenzene		ND	ND	NA
9.	Hexachlorobenzene		ND	ND	NA
10.	1, 2 Dichloroethane		ND	ND	ND
11.	1,1,1 Trichlorethane		*	ND	ND
12.	Hexachloroethane		ND	ND	NA
13.	1,1 Dichloroethane		ND	ND	ND
14.	1,1,2 Trichloroethane		ND	ND	ND
15.	1,1,2,2 Tetrachloroethane		ND	*	ND
16.	Chloroethane		ND	ND	NA
17.	Bis Chloromethyl Ether		ND	ND	NA
18.	Bis 2-Chloroethyl Ether		ND	ND	NA
19.	2-Chloroethyl Vinyl Ether		ND	ND	NA
20.	2-Chloronaphthalene		ND	ND	NA
21.	2,4,6 Trichlorophenol		ND	ND	NA
22.	Parachlorometacresol		ND	ND	NA
23.	Chloroform		0.043	*	ND
24.	2 Chlorophenol		ND	ND	NA
25.	1,2 Dichlorobenzene		ND	ND	NA
26.	1,3 Dichlorobenzene		ND	ND	NA
27.	1,4 Dichlorobenzene		ND	ND	NA
28.	3,3 Dichlorobenzidine		ND	ND	NA
29.	1,1 Dichloroethylene		ND	ND	ND
30.	1,2 Trans-Dichloroethylene		ND	ND	NA
31.	2,4 Dichlorophenol		ND	ND	NA
32.	1,2 Dichloropropane		ND	ND	ND
33.	1,2 Dichloropropylene		ND	ND	ND
34.	2,4 Dimethylphenol		ND	ND	ND
35.	2,4 Dinitrotoluene		ND	ND	NA
36.	2,6 Dinitrotoluene		ND	ND	NA
37.	1,2 Diphenylhydrazine		ND	ND	NA
38.	Ethylbenzene		ND	ND	ND
39.	Fluoranthene		ND	ND	NA
40.	4 Chlorophenyl Phenyl Ether		ND	ND	NA
41.	4 Bromophenyl Phenyl Ether		ND	ND	NA
42.	Bis (2 Chloroisopropyl) Ether		ND	ND	NA
43.	Bis (2 Chloroethoxy) Methane		ND	ND	NA
44.	Methylene Chloride	1,0	*	ND	0.006
45.	Methyl Chloride		ND	ND	ND
46.	Methy Bromide		ND	ND	ND
47.	Bromoform		ND	ND	ND
48.	Dichlorobromomethane		0.010	ND	ND
49.	Trichlorofluoromethane		ND	ND	ND
50.	Dichlorodifluoromethane		ND	ND	ND

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TABLE V-4
SCREENING ANALYSIS RESULTS (CONT.)
LECLANCHE SUBCATEGORY

	DCP data KTBP, BTBP	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Analysis Blank Conc. mg/1
51. Chlorodibromomethane		*	ND	ND
52. Hexachlorobutadiene		ND	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	NA
54. Isophorone		ND	ND	NA
55. Naphthalene		ND	ND	NA
56. Nitrobenzene		ND	ND	NA
57. 2 Nitrophenol		ND	ND	NA
58. 4 Nitrophenol		ND	ND	NA
59. 2,4 Dinitrophenol		ND	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	NA
61. N-Nitrosodimethylamine		ND	ND	NA
62. B-Nitrosodipehnylamine		ND	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	NA
64. Pentachlorophenol		ND	ND	NA
65. Phenol		ND	*	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	*	NA
67. Butyl Benzyl Phthalate		ND	*	NA
68. Di-N-butyl Phthalate		ND	*	NA
69. Di-N-octyl Phthalate	0,1	*	ND	NA
70. Diethyl Phthalate		ND	.016	NA
71. Dimethyl Phthalate		*	*	NA
72. 1,2 Benzanthracene		ND	ND	NA
73. Benzo (A) Pyrene		ND	ND	NA
74. 3,4 Benzofluoranthene		ND	ND	NA
75. 11, 12-Benzofluoranthene		ND	ND	NA
76. Chrysene		ND	ND	NA
77. Acenaphthylene		ND	ND	NA
78. Anthracene		ND	ND	NA
79. 1,12-Benzoperylene		ND	ND	NA
80. Fluorene		ND	ND	NA
81. Phenanthrene		ND	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	NA
83. Indenopyrene		ND	ND	NA
84. Pyrene		ND	ND	NA
85. Tetrachloroethylene	0,1	ND	ND	ND
86. Toluene	0,2	*	ND	ND
87. Trichloroethylene	0,1	ND	ND	ND
88. Vinyl Chloride	0,1	ND	ND	ND
89. Aldrin		ND	ND	NA
90. Dieldrin		ND	ND	NA
91. Chlordane		ND	ND	NA
92. 4,4 DDT		ND	ND	NA
93. 4,4 DDE		ND	ND	NA
94. 4,4 DDD		ND	ND	NA
95. Alpha-Endosulfan		ND	ND	NA
96. Beta-Endosulfan		ND	ND	NA
97. Endosulfan Sulfate		ND	ND	NA
98. Endrin		ND	ND	NA
99. Endrin Aldehyde		ND	ND	NA
100. Heptachlor		ND	ND	NA

TABLE V-4
SCREENING ANALYSIS RESULTS (CONT.)
LECLANCHE SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
101. Heptachlor Epoxide		ND	ND	NA
102. AlphaBHC		ND	ND	NA
103. BetaBHC		ND	ND	NA
104. GammaBHC (Lindane)		ND	ND	NA
105. DeltaBHC		ND	ND	NA
106. PCB1242		ND	ND	NA
107. PCB1254		ND	ND	NA
108. PCB1221		ND	ND	NA
109. PCB1232		ND	ND	NA
110. PCB1248		ND	ND	NA
111. PCB1260		ND	ND	NA
112. PCB1016		ND	ND	NA
113. Toxaphene		ND	ND	NA
114. Antimony	0,3	ND	1.00	NA
115. Arsenic	0,4	ND	ND	NA
116. Asbestos		ND	ND	NA
117. Beryllium		<0.001	<0.01	NA
118. Cadmium	0,5	<0.002	0.10	NA
119. Chromium	1,2	<0.005	0.20	NA
120. Copper	4,2	<0.009	1.00	NA
121. Cyanide		ND	.018	NA
122. Lead	4,3	<0.02	6.00	NA
123. Mercury	5,1	0.020	6.00	NA
124. Nickel	1,3	<0.005	4.00	NA
125. Selenium	1,0	ND	ND	NA
126. Silver		<0.001	<0.01	NA
127. Thallium		ND	ND	NA
128. Zinc	0,2	0.080	2000	NA
129. 2,3,7,8 TCDD (Dioxin)		NA	NA	NA
130. Xylenes		NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA
Aluminum		<0.09	<0.09	NA
Ammonia	-,-	NA	ND	NA
Barium	-,-	0.010	0.40	NA
Boron	-,-	0.100	2.00	NA
Calcium	-,-	52.000	150	NA
Cobalt	-,-	<0.002	<0.02	NA
Fluoride	-,-	1.200	2.20	NA
Gold	-,-	ND	ND	NA
Iron	-,-	< 0.1	5.00	NA
Magnesium	-,-	7.500	33.0	NA
Manganese	-,-	0.02	10.0	NA
Molybdenum	-,-	<0.006	0.20	NA
Oil and Grease	-,-	ND	ND	NA
Phenols (Total)	-,-	1.600	14.9	NA
Phosphorus	-,-	0.240	.82	NA
Sodium	-,-	66.00	180	NA
Strontium	-,-	NA	NA	NA
TSS	-,-	ND	1630	NA
Tin	-,-	<0.008	3.00	NA
Titanium	-,-	<0.006	ND	NA
Vanadium	-,-	< 0.002	ND	NA
Yttrium	-,-	< 0.002	ND	NA

TABLE V-4
SCREENING ANALYSIS RESULTS (CONT.)
LECLANCHE SUBCATEGORY

DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l

ND   .Not detected

NA   Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis were not finalized for these parameters).

KTBP   Known to be present indicated by number of plants.

BTBP   Believed to be present indicated by number of plants.

-,-   Not investigated in DCP survey.

*   Indicates less than .01 mg/l.

**   Indicates less than .005 mg/l.

TABLE V-5
SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
1.	Acenaphthene	ND	ND	NA	ND	NA
2.	Acrolein	ND	ND	ND	ND	ND
3.	Acrylonitrile	ND	ND	ND	ND	ND
4.	Benzene	ND	ND	ND	ND	ND
5.	Benzidine	ND	ND	NA	ND	NA
6.	Carbon Tetrachloride	ND	ND	ND	ND	ND
7.	Chlorobenzene	ND	ND	ND	ND	ND
8.	1,2,4 Trichlorobenzene	ND	ND	NA	ND	NA
9.	Hexachlorobenzene	ND	ND	NA	ND	NA
10.	1,2 Dichloroethane	ND	ND	ND	ND	ND
11.	1,1,1 Trichloroethane	ND	ND	ND	*	ND
12.	Hexachloroethane	ND	ND	NA	ND	NA
13.	1,1 Dichloroethane	ND	ND	ND	ND	ND
14.	1,1,2 Trichloroethane	ND	0.013	ND	ND	ND
15.	1,1,2,2 Tetrachloroethane	ND	ND	ND	ND	ND
16.	Chloroethane	ND	ND	ND	ND	ND
17.	Bis Chloromethyl Ether	ND	ND	ND	ND	ND
18.	Bis 2-Chloroethyl Ether	ND	ND	NA	ND	NA
19.	2-Chloroethyl Vinyl Ether	ND	ND	ND	ND	ND
20.	2-Chloronaphthalene	ND	ND	NA	ND	NA
21.	2,4,6 Trichlorophenol	ND	ND	NA	ND	NA
22.	Parachlorometacresol	ND	ND	NA	ND	NA
23.	Chloroform	0.055	0.038	*	0.012	*
24.	2 Chlorophenol	ND	ND	NA	ND	NA
25.	1,2 Dichlorobenzene	ND	ND	NA	ND	NA

TABLE V-5 (CON'T)
SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/1	Raw[1] Waste Conc. mg/1	Analysis Blank Conc. mg/1	Raw[2] Waste Conc. mg/1	Analysis Blank Conc. mg/1
26. 1,3 Dichlorobenzene		ND	ND	NA	ND	NA
27. 1,4 Dichlorobenzene		ND	ND	NA	ND	NA
28. 3,3 Dichlorobenzidine		ND	ND	NA	ND	NA
29. 1,1 Dichloroethylene		ND	ND	ND	ND	ND
30. 1,2 Trans-Dichloroethylene		ND	ND	ND	ND	ND
31. 2,4 Dichlorophenol		ND	ND	NA	ND	NA
32. 1,2 Dichloropropane		ND	ND	ND	ND	ND
33. 1,2 Dichloropropylene		ND	ND	ND	ND	ND
34. 2,4 Dimethylphenol		ND	ND	NA	ND	NA
35. 2,4 Dinitrotoluene		ND	ND	NA	ND	NA
36. 2,6 Dinitrotoluene		ND	ND	NA	ND	NA
37. 1,2 Diphenylhydrazine		ND	ND	NA	ND	NA
38. Ethylbenzene		ND	ND	ND	ND	ND
39. Fluoranthene		ND	ND	NA	ND	NA
40. 4 Chlorophenyl Phenyl Ether		ND	ND	NA	ND	NA
41. 4 Bromophenyl Phenyl Ether		ND	ND	NA	ND	NA
42. Bis (2-Chloroisopropyl) Ether		ND	ND	NA	ND	NA
43. Bis (2-Chloroethoxy) Methane		ND	ND	NA	ND	NA
44. Methylene Chloride		0.011	0.014	*	0.016	*
45. Methyl Chloride		ND	ND	ND	ND	ND
46. Methyl Bromide		ND	ND	ND	ND	ND
47. Bromoform		ND	ND	ND	ND	ND
48. Dichlorobromomethane		ND	ND	ND	ND	ND
49. Trichlorofluoromethane		ND	ND	ND	ND	ND
50. Dichlorodifluoromethane		ND	ND	ND	ND	ND

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TABLE V-5 (CON'T)
SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
51. Chlorodibromomethane		ND	ND	ND	ND	ND
52. Hexachlorobutadiene		ND	ND	NA	ND	NA
53. Hexachlorocyclopentadiene		ND	ND	NA	ND	NA
54. Isophorone		ND	ND	NA	ND	NA
55. Naphthalene		ND	ND	NA	ND	NA
56. Nitrobenzene		ND	ND	NA	ND	NA
57. 2 Nitrophenol		ND	ND	NA	ND	NA
58. 4 Nitrophenol		ND	ND	NA	ND	NA
59. 2,4 Dinitrophenol		ND	ND	NA	ND	NA
60. 4,6 Dinitro-o-cresol		ND	ND	NA	ND	NA
61. N-Nitrosodimethylamine		ND	ND	NA	ND	NA
62. N-Nitrosodiphenylamine		ND	ND	NA	ND	NA
63. N-Nitrosodi-N-propylamine		ND	ND	NA	ND	NA
64. Pentachlorophenol		*	*	NA	ND	NA
65. Phenol		ND	ND	NA	ND	NA
66. Bis (2-Ethylhexyl) Phthalate		ND	0.024	NA	0.013	NA
67. Butyl Benzyl Phthalate		ND	ND	NA	*	NA
68. Di-N-butyl Phthalate		*	*	NA	ND	NA
69. Di-N-octyl Phthalate		ND	ND	NA	ND	NA
70. Diethyl Phthalate		ND	ND	NA	ND	NA
71. Dimethyl Phthalate		ND	ND	NA	ND	NA
72. 1,2 Benzanthracene		ND	ND	NA	ND	NA
73. Benzo (A) Pyrene		ND	ND	NA	ND	NA
74. 3,4 Benzofluoranthene		ND	ND	NA	ND	NA
75. 11, 12-Benzofluoranthene		ND	ND	NA	ND	NA

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TABLE V-5 (CON'T)

SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

		DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
76.	Chrysene		ND	ND	NA	ND	NA
77.	Acenaphthylene		ND	ND	NA	ND	NA
78.	Anthracene		ND	ND	NA	ND	NA
79.	1,12-Benzoperylene		ND	ND	NA	ND	NA
80.	Fluorene		ND	ND	NA	ND	NA
81.	Phenanthrene		ND	ND	NA	ND	NA
82.	1,2,5,6 Dibenzanthracene		ND	ND	NA	ND	NA
83.	Indenopyrene		ND	ND	NA	ND	NA
84.	Pyrene		ND	ND	NA	ND	NA
85.	Tetrachloroethylene		ND	ND	ND	ND	ND
86.	Toluene		ND	*	ND	*	ND
87.	Trichloroethylene		ND	ND	ND	ND	ND
88.	Vinyl Chloride		ND	ND	ND	ND	ND
89.	Aldrin		ND	ND	NA	ND	NA
90.	Dieldrin		ND	ND	NA	ND	NA
91.	Chlordane		ND	ND	NA	ND	NA
92.	4,4 DDT		ND	ND	NA	ND	NA
93.	4,4 DDE		ND	ND	NA	ND	NA
94.	4,4 DDD		ND	ND	NA	ND	NA
95.	Alpha-Endosulfan		ND	ND	NA	ND	NA
96.	Beta-Endosulfan		ND	ND	NA	ND	NA
97.	Endosulfan Sulfate		ND	ND	NA	ND	NA
98.	Endrin		ND	ND	NA	ND	NA
99.	Endrin Aldehyde		ND	ND	NA	ND	NA
100.	Heptachlor		ND	ND	NA	ND	NA

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TABLE V-5 (CON'T)

SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

		DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
101.	Heptachlor Epoxide		ND	ND	NA	ND	NA
102.	Alpha-BHC		ND	ND	NA	ND	NA
103.	Beta-BHC		ND	ND	NA	ND	NA
104.	Gamma-BHC (Lindane)		ND	ND	NA	ND	NA
105.	Delta-BHC		ND	ND	NA	ND	NA
106.	PCB-1242		ND	ND	NA	ND	NA
107.	PCB-1254		ND	ND	NA	ND	NA
108.	PCB-1221		ND	ND	NA	ND	NA
109.	PCB-1232		ND	ND	NA	ND	NA
110.	PCB-1248		ND	ND	NA	ND	NA
111.	PCB-1260		ND	ND	NA	ND	NA
112.	PCB-1016		ND	ND	NA	ND	NA
113.	Toxaphene		ND	ND	NA	ND	NA
114.	Antimony		<0.005	<0.005	NA	<0.005	NA
115.	Arsenic		<0.005	<0.005	NA	<0.005	NA
116.	Asbestos				NA		NA
117.	Beryllium		<0.001	<0.001	NA	<0.001	NA
118.	Cadmium	0,1	0.001	0.002	NA	0.025	NA
119.	Chromium	0,1	0.005	2.06	NA	0.015	NA
120.	Copper		0.068	0.118	NA	0.109	NA
121.	Cyanide		ND	0.00	NA	0.14	NA
122.	Lead	0,1	0.025	0.044	NA	4.93	NA
123.	Mercury		<0.001	<0.001	NA	<0.001	NA
124.	Nickel		0.060	0.067	NA	0.235	NA
125.	Selenium		<0.005	<0.005	NA	<0.005	NA

TABLE V-5 (CON'T)

SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

		DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw[1] Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw[2] Waste Conc. mg/l	Analysis Blank Conc. mg/l
126.	Silver		0.003	0.012	NA	0.001	NA
127.	Thallium		<0.050	<0.050	NA	<0.050	NA
128.	Zinc		0.018	0.045	NA	0.473	NA
129.	2,3,7,8 TCDD (Dioxin)		ND	ND	NA	ND	NA
130.	Xylenes		NA	NA	NA	NA	NA
131.	Alkyl Epoxides		NA	NA	NA	NA	NA
	Aluminum	-,-	0.086	0.104	NA	0.287	NA
	Ammonia	-,-	NA	NA	NA	NA	NA
	Barium	-,-	0.016	2.67	NA	0.059	NA
	Boron	-,-	0.040	0.116	NA	0.193	NA
	Calcium	-,-	15.4	15.9	NA	22.8	NA
	Cobalt	-,-	0.011	0.006	NA	0.176	NA
	Fluoride	-,-	1.7	1.7	NA	3.05	NA
	Gold	-,-			NA		NA
	Iron	-,-	0.091	0.122	NA	54.9	NA
	Lithium		<0.050	<0.050	NA	<0.050	NA
	Magnesium	-,-	3.47	3.66	NA	3.78	NA
	Manganese	-,-	0.007	0.008	NA	1.60	NA
	Molybdenum	-,-	<0.001	0.001	NA	0.021	NA
	Oil and Grease	-,-	ND	0	NA	ND	NA
	Phenols (Total)	-,-	ND	0.00	NA	ND	NA
	Phosphorus	-,-	0	0	NA	1.56	NA
	Sodium	-,-	5.73	6.06	NA	6.44	NA
	Strontium	-,-			NA		NA
	TSS	-,-	ND	21.0	NA	39.0	NA
	Tin	-,-	0.012	0.006	NA	0.023	NA
	Titanium	-,-	0.001	0.001	NA	0.001	NA
	Vanadium	-,-	0.030	0.030	NA	0.035	NA
	Yttrium	-,-	<0.001	<0.001	NA	0.023	NA

TABLE V-5 (CON'T)
SCREENING ANALYSIS RESULTS

LITHIUM SUBCATEGORY

DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l

ND   Not detected

NA   Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis were not finalized for these parameters).

KTBP   Known to be present indicated by number of plants.

BTBP   Believed to be present indicated by number of plants.

-,-   Not investigated in DCP survey.

*   Indicates less than .01 mg/l.

**   Indicates less than .005 mg/l.

1.   Heat Paper Production Wastewater

2.   Cathode Process Wastewater

Table V-6

SCREENING ANALYSIS RESULTS

MAGNESIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
1. Acenaphthene		ND	ND	NA
2. Acrolein		ND	ND	ND
3. Acrylontirile		ND	ND	ND
4. Benzene		ND	ND	ND
5. Benzidine		ND	ND	NA
6. Carbon Tetrachloride		ND	ND	ND
7. Chlorobenzene _		ND	ND	ND
8. 1,2,4 Trichlorobenzene		ND	ND	NA
9. Hexachlorobenzene		ND	ND	NA
10. 1,2 Dichloroethane		ND	ND	ND
11. 1,1,1 Trichloroethane		ND	ND	ND
12. Hexachloroethane		ND	ND	NA
13. 1,1 Dichloroethane		ND	ND	ND
14. 1,1,2 Trichloroethane		ND	0.013	ND
15. 1,1,2,2 Tetrachloroethane		ND	ND	ND
16. Chloroethane		ND	ND	ND
17. Bis Chloromethyl Ether		ND	ND	ND
18. Bis 2-Chloroethyl Ether		ND	ND	NA
19. 2-Chloroethyl Vinyl Ether		ND	ND	ND
20. 2-Chloronapthalene		ND	ND	NA
21. 2,4,6 Trichlorophenol		ND	ND	NA
22. Parachlorometacresol		ND	ND	NA
23. Chloroform		0.055	0.038	*
24. 2 Chlorophenol		ND	ND	NA
25. 1,2 Dichlorobenzene		ND'	ND	NA
26. 1,3 Dichlorobenzene		ND	ND	NA
27. 1,4 Dichlorobenzene		ND	ND	NA
28. 3,3 Dichlorobenzidine		ND	ND	NA
29. 1,1 Dichloroethylene		ND	ND	ND
30. 1,2 Trans-Dichloroethylene		ND	ND	ND
31. 2,4 Dichlorophenol		ND	ND	NA
32. 1,2 Dichloropropane		ND	ND	ND
33. 1,2 Dichloropropylene		ND	ND	ND
34. 2,4 Dimethylphenol		ND	ND	NA
35. 2,4 Dinitrotoluene		ND	ND	NA
36. 2,6 Dinitrotoluene		ND	ND	NA
37. 1,2 Diphenylhydrazine		ND	ND	NA
38. Ethylbenzene		ND	ND	ND
39. Fluoranthene		ND	ND	NA
-40. 4 Chlorophenyl Phenyl Ether		ND	ND	NA

TABLE V-6
SCREENING ANALYSIS RESULTS (CONT.)
MAGNESIUM SUBCATEGORY

		DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
41.	4 Bromophenyl Phenyl Ether		ND	ND	NA
42.	Bis (2 Chloroisopropyl) Ether		ND	ND	NA
43.	Bis (2 Chloroethoxy) Methane		ND	ND	NA
44.	Methylene Chloride		0.011	0.014	*
45.	Methyl Chloride		ND	ND	ND
46.	Methyl Bromide		ND	ND	ND
47.	Bromoform		ND	ND	ND
48.	Dichlorobromomethane		ND	ND	ND
49.	Trichlorofluoromethane		ND	ND	ND
50.	Dichlorodifluoromethane		ND	ND	ND
51.	Chlorodibromomethane		ND	ND	ND
52.	Hexachlorobutadiene		ND	ND	NA
53.	Hexachlorocyclopentadiene		ND	ND	NA
54.	Isophorone		ND	ND	NA
55.	Naphthalene		ND	ND	NA
56.	Nitrobenzene		ND	ND	NA
57.	2 Nitrophenol		ND	ND	NA
58.	4 Nitrophenol		ND	ND	NA
59.	2,4 Dinitrophenol		ND	ND	NA
60.	4,6 Dinitro-o-cresol		ND	ND	NA
61.	N-Nitrosodimethylamine		ND	ND	NA
62.	N-Nitrosodiphenylamine		ND	ND	NA
63.	N-Nitrosodi-N-propylamine		ND	ND	NA
64.	Pentachlorophenol		*	*	NA
65.	Phenol		ND	ND	NA
66.	Bis (2-Ethylhexyl) Phthalate		ND	0.024	NA
67.	Butyl Benzyl Phthalate		ND	ND	NA
68.	Di-N-butyl Phthalate		*	*	NA
69.	Di-N-octyl Phthalate		ND	ND	NA
70.	Diethyl Phthalate		ND	ND	NA
71.	Dimethyl Phthalate		ND	ND	NA
72.	1,2 Benzanthracene		ND	ND	NA
73.	Benzo (A) Pyrene		ND	ND	NA
74.	3,4 Benzofluorathene		ND	ND	NA
75.	11, 12-Benzofluoranthene		ND	ND	NA
76.	Chrysene		ND	ND	NA
77.	Acenaphthylene		ND	ND	NA
78.	Anthracene		ND	ND	NA
79.	1,12-Benzoperylene		ND	ND	NA
80.	Fluorene		ND	ND	NA

TABLE V-6

SCREENING ANALYSIS RESULTS (CONT.)

MAGNESIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
81. Phenanthrene		ND	ND	NA
82. 1,2,5,6 Dibenzanthracene		ND	ND	NA
83. Indenopyrene		ND	ND	NA
84. Pyrene		ND	ND	NA
85. Tetrachloroethylene		ND	ND	ND
86. Toluene		ND	*	ND
87. Trichloroethylene		ND	ND	ND
88. Vinyl Chloride		ND	ND	ND
89. Aldrin		ND	ND	NA
90. Dieldrin		ND	ND	NA
91. Chlordane		ND	ND	NA
92. 4,4 DDT		ND	ND	NA
93. 4,4 DDE		ND	ND	NA
94. 4,4 DDD		ND	ND	NA
95. Alpha-Endosulfan		ND	ND	NA
96. Beta-Endosulfan		ND	ND	NA
97. Endosulfan Sulfate		ND	ND	NA
98. Endrin		ND	ND	NA
99. Endrin Aldehyde		ND	ND	NA
100. Heptachlor		ND	ND	NA
101. Heptachlor Epoxide		ND	ND	NA
102. Alpha-BHC		ND	ND	NA
103. Beta-BHC		ND	ND	NA
104. Gamma-BHC (Lindane)		ND	ND	NA
105. Delta-BHC		ND	ND	NA
106. PCB-1242		ND	ND	NA
107. PCB-1254		ND	ND	NA
108. PCB-1221		ND	ND	NA
109. PCB=1232		ND	ND	NA
110. PCB-1248		ND	ND	NA
111. PCB-1260		ND	ND	NA
112. PCB-1016		ND	ND	NA
113. Toxaphene		ND	ND	NA
114. Antimony		<0.005	<0.005	NA
115. Arsenic		<0.005	<0.005	NA
116. Asbestos				NA
117. Beryllium		<0.001	<0.001	NA
118. Cadmium	0,1	0.001	0.001	NA
119. Chromium	0,2	0.005	2.06	NA
120. Copper		0.068	0.118	NA

TABLE V-6
SCREENING ANALYSIS RESULTS (CONT.)
MAGNESIUM SUBCATEGORY

	DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l
121. Cyanide		ND	ND	NA
122. Lead		0.025	0.044	NA
123. Mercury		0.001	0.001	NA
124. Nickel		0.060	0.067	NA
125. Selenium		<0.005	<0.005	NA
126. Silver		0.003	0.012	NA
127. Thallium		<0.050	<0.050	NA
128. Zinc		0.018	0.045	NA
129. 2,3,7,8 TCDD (Dioxin)		ND	ND	NA
130. Xylenes		NA	NA	NA
131. Alkyl Epoxides		NA	NA	NA
Aluminum	-,-	0.086	0.104	NA
Ammonia	-,-	NA	NA	NA
Barium	-,-	0.016	2.67	NA
Boron	-,-	0.040	0.116	NA
Calcium	-,-	15.4	15.9	NA
Cobalt	-,-	0.011	0.006	NA
Fluoride	-,-	1.7	1.7	NA
Gold	-,-	NA	NA	NA
Iron	-,-	0.091	0.122	NA
Magnesium	-,-	3.47	3.66	NA
Manganese	-,-	0.007	0.008	NA
Molybdenum	-,-	<0.001	0.001	NA
Oil and Grease	-,-	ND	ND	NA
Phenols (Total)	-,-	ND	ND	NA
Phosphorus	-,-	ND	ND	NA
Sodium	-,-	5.73	6.06	NA
Strontium	-,-	NA	NA	NA
TSS	-,-	ND	21	NA
Tin	-,-	0.012	0.006	NA
Titanium	-,-	0.001	0.001	NA
Vanadium	-,-	0.030	0.030	NA
Yttrium	-,-	<0.001	0.001	NA

TABLE V-6

SCREENING ANALYSIS RESULTS (CONT.)

MAGNESIUM SUBCATEGORY

DPC Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Analysis Blank Conc. mg/l

ND   Not detected

NA   Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis were not finalized for these parameters).

KTBP Known to be present indicated by number of plants.

BTBP Believed to be present indicated by number of plants.

-,- Not investigated in DCP survey.

*   Indicates less than 0.01 mg/l.

**   Indicates less than 0.005 mg/l.

TABLE V-7
SCREENING ANALYSIS RESULTS
ZINC SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
1 Acenaphthene		ND	NA	ND	NA	ND	ND	ND	NA
2 Acrolein		ND	ND	ND	ND	ND	ND	ND	ND
3 Acrylonitrile		ND	ND	ND	ND	ND	ND	ND	ND
4 Benzene		ND	*	*	ND	ND	ND	ND	ND
5 Benzidine		ND	NA	ND	NA	ND	ND	ND	NA
6 Carbon Tetrachloride		ND	ND	ND	ND	ND	ND	ND	ND
7 Chlorobenzene		ND	ND	ND	ND	ND	ND	ND	ND
8 1,2,4 Trichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
9 Hexachlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
10 1,2 Dichloroethane		ND	ND	ND	ND	ND	ND	ND	ND
11 1,1,1 Trichloroethane	1,0	ND	4.2	6.4	ND	ND	*	*	ND
12 Hexachloroethane		ND	NA	ND	NA	ND	ND	ND	NA
13 1,1 Dichloroethane		ND	0.018	0.079	ND	ND	*	ND	ND
14 1,1,2 Trichloroethane		ND	ND	*	ND	ND	ND	ND	ND
15 1,1,2,2 Tetrachloroethane		ND	ND	ND	ND	ND	ND	ND	ND
16 Chloroethane		ND	ND	ND	ND	ND	ND	ND	ND
17 Bis Chloromethyl Ether		ND	ND	ND	ND	ND	ND	ND	ND
18 Bis 2-Chloroethyl Ether		ND	ND	ND	NA	ND	ND	ND	NA
19 2-Chloroethyl Vinyl Ether		ND	ND	ND	ND	ND	ND	ND	NA
20 2-Chloronaphthalene		ND	NA	ND	NA	ND	ND	ND	NA
21 2,4,6 Trichlorophenol		ND	NA	*	NA	ND	ND	ND	NA
22 Parachlorometacresol		ND	NA	ND	NA	ND	ND	ND	NA
23 Chloroform		0.086	ND	ND	ND	ND	ND	ND	ND
24 Chlorophenol		ND	NA	*	NA	ND	ND	ND	NA
25 1,2 Dichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
26 1,3 Dichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
27 1,4 Dichlorobenzene		ND	NA	ND	NA	ND	ND	ND	NA
28 3,3 Dichlorobenzidine		ND	NA	ND	NA	ND	ND	ND	NA
29 1,1 Dichloroethylene		ND	0.64	0.42	ND	ND	ND	ND	ND
30 1,2 Trans-Dichloroethylene		ND	0.016	ND	ND	ND	ND	ND	ND
31 2,4 Dichlorophenol		ND	NA	ND	NA	ND	ND	ND	NA
32 1,2 Dichloropropane		ND	ND	ND	ND	ND	ND	ND	ND
33 1,2 Dichloropropylene		ND	ND	ND	ND	ND	ND	ND	ND
34 2,4 Dimethylphenol		ND	NA	ND	NA	ND	ND	ND	NA
35 2,4 Dinitrotoluene		ND	NA	ND	NA	ND	ND	ND	NA
36 2,6 Dinitrotoluene		ND	NA	ND	NA	ND	ND	ND	NA
37 1,2 Diphenylhydrazine		ND	NA	ND	NA	ND	ND	ND	NA
38 Ethylbenzene		ND	*	0.032	ND	ND	ND	ND	ND

TABLE V-7
SCREENING ANALYSIS RESULTS (CONT.)
ZINC SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
39 Fluoranthene		ND	NA	ND	NA	ND	ND	ND	NA
40 4 Chlorophenyl Phenyl Ether		ND	NA	ND	NA	ND	ND	ND	NA
41 4 Bromophenyl Phenyl Ether		ND	NA	ND	NA	ND	ND	ND	NA
42 Bis(2 Chloroisopropyl) Ether		ND	NA	ND	NA	ND	ND	ND	NA
43 Bis(2 Chloroethoxy) Methane		ND	NA	ND	NA	ND	ND	ND	NA
44 Methylene Chloride	1,1	ND	0.35	8.4	ND	ND	0.022	0.031	0.018
45 Methyl Chloride		ND	ND	ND	ND	ND	ND	ND	ND
46 Methyl Bromide		ND	ND	ND	ND	ND	ND	ND	ND
47 Bromoform		ND	ND	ND	ND	ND	ND	ND	ND
48 Dichlorobromomethane		ND	ND	ND	ND	ND	ND	ND	ND
49 Trichlorofluoromethane		ND	ND	ND	ND	ND	ND	ND	ND
50 Dichlorodifluoromethane		ND	ND	ND	ND	ND	ND	ND	ND
51 Chlorodibromomethane		ND	ND	ND	ND	ND	ND	ND	ND
52 Hexachlorobutadiene		ND	NA	ND	NA	ND	ND	ND	NA
53 Hexachlorocyclopentadiene		ND	NA	ND	NA	ND	ND	ND	NA
54 Isophorone		ND	NA	ND	NA	ND	ND	ND	NA
55 Naphthalene		ND	NA	0.190	NA	ND	ND	ND	NA
56 Nitrobenzene		ND	NA	ND	NA	ND	ND	ND	NA
57 2 Nitrophenol		ND	NA	ND	NA	ND	ND	ND	NA
58 4 Nitrophenol		ND	NA	ND	NA	ND	ND	ND	NA
59 2,4 Dinitrophenol		ND	NA	ND	NA	ND	ND	ND	NA
60 4,6 Dinitro-o-cresol		ND	NA	ND	NA	ND	ND	ND	NA
61 N-Nitrosodimethylamine		ND	NA	ND	NA	ND	ND	ND	NA
62 N-Nitrosodiphenylamine		ND	NA	ND	NA	ND	ND	ND	NA
63 N-Nitrosodi-N-propylamine		ND	NA	ND	NA	ND	ND	ND	NA
64 Pentachlorophenol		ND	NA	ND	NA	ND	0.040	0.027	NA
65 Phenol		ND	NA	0.06	NA	ND	ND	*	NA
66 Bis (2-Ethylhexyl) Phthalate		*	NA	*	NA	ND	0.012	0.031	NA
67 Butyl Benzyl Phthalate		ND	NA	ND	NA	ND	*	*	NA
68 Di-N-butyl Phthalate		*	NA	*	NA	*	*	*	NA
69 Di-N-octyl Phthalate		ND	NA	ND	NA	ND	ND	ND	NA
70 Diethyl Phthalate		ND	NA	*	NA	ND	ND	ND	NA
71 Dimethyl Phthalate		ND	NA	ND	NA	ND	ND	ND	NA
72 1,2 Benzanthracene		ND	NA	ND	NA	ND	ND	ND	NA
73 Benzo (A) Pyrene		ND	NA	ND	NA	ND	ND	ND	NA
74 3,4 Benzofluoranthene		ND	NA	ND	NA	ND	ND	ND	NA
75 11,12-Benzofluoranthene		ND	NA	ND	NA	ND	ND	ND	NA
76 Chrysene		ND	NA	ND	NA	ND	ND	ND	NA
77 Acenaphthylene		ND	NA	ND	NA	ND	ND	NA	

TABLE V-7
SCREENING ANALYSIS RESULTS (CONT.)
ZINC SUBCATEGORY

	DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
78 Anthracene		ND	NA	ND	NA	ND	*	ND	NA
79 1,12-Benzoperylene		ND	NA	ND	NA	ND	ND	ND	NA
80 Fluorene		ND	NA	ND	NA	ND	ND	ND	NA
81 Phenanthrene		ND	NA	ND	NA	ND	*	ND	NA
82 1,2,5,6 Dibenzanthracene		ND	NA	ND	NA	ND	ND	ND	NA
83 Indenopyrene		ND	NA	ND	NA	ND	ND	ND	NA
84 Pyrene		ND	NA	ND	NA	ND	ND	ND	NA
85 Tetrachloroethylene		ND	0.025	*	ND	ND	*	*	ND
86 Toluene	0,1	ND	0.11	0.055	ND	ND	*	*	ND
87 Trichloroethylene	2,0	ND	0.39	0.045	ND	ND	*	*	ND
88 Vinyl Chloride		ND	ND	ND	ND	ND	ND	ND	ND
89 Aldrin		ND	NA	ND	NA	ND	ND	ND	NA
90 Dieldrin		ND	NA	ND	NA	ND	ND	ND	NA
91 Chlordane		ND	NA	ND	NA	ND	ND	ND	NA
92 4,4 DDT		ND	NA	ND	NA	ND	ND	ND	NA
93 4,4 DDE		ND	NA	ND	NA	ND	ND	ND	NA
94 4,4 DDD		ND	NA	ND	NA	ND	ND	ND	NA
95 Alpha-Endosulfan		ND	NA	ND	NA	ND	ND	ND	NA
96 Beta-Endosulfan		ND	NA	ND	NA	ND	ND	ND	NA
97 Endosulfan Sulfate		ND	NA	ND	NA	ND	ND	ND	NA
98 Endrin		ND	NA	ND	NA	ND	ND	ND	NA
99 Endrin Aldehyde		ND	NA	ND	NA	ND	ND	ND	NA
100 Heptachlor		ND	NA	ND	NA	ND	ND	ND	NA
101 Heptachlor Epoxide		ND	NA	ND	NA	ND	ND	ND	NA
102 Alpha-BHC		ND	NA	ND	NA	ND	ND	ND	NA
103 Beta-BHC		ND	NA	ND	NA	ND	ND	ND	NA
104 Gamma-BHC (Lindane)		ND	NA	ND	NA	ND	ND	ND	NA
105 Delta-BHC		ND	NA	ND	NA	ND	ND	ND	NA
106 PCB-1242		ND	NA	ND	NA	ND	ND	ND	NA
107 PCB-1254		ND	NA	ND	NA	ND	ND	ND	NA
108 PCB-1221		ND	NA	ND	NA	ND	ND	ND	NA
109 PCB-1232		ND	NA	ND	NA	ND	ND	ND	NA
110 PCB-1248		ND	NA	ND	NA	ND	ND	ND	NA
111 PCB-1260		ND	NA	ND	NA	ND	ND	ND	NA
112 PCB-1016		ND	NA	ND	NA	ND	ND	ND	NA
113 Toxaphene		ND	NA	ND	NA	ND	ND	ND	NA
114 Antimony	1,0	ND	0.07	ND	NA	ND	ND	ND	NA
115 Arsenic	1,0	ND	ND	ND	NA	ND	ND	ND	NA
116 Asbestos		ND	ND	ND	NA	ND	ND	ND	NA

TABLE V-7
SCREENING ANALYSIS RESULTS (CONT.)
ZINC SUBCATEGORY

		DCP Data KTBP, BTBP	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l	Plant Influent Conc. mg/l	Raw Waste Conc. mg/l	Effluent Conc. mg/l	Analysis Blank Conc. mg/l
117	Beryllium		<0.001	<0.001	<0.001	NA	<0.001	ND	<0.001	NA
118	Cadmium	0,1	<0.002	0.16	<0.002	NA	<0.002	0.060	0.030	NA
119	Chromium	5,0	<0.005	2.13	<0.005	NA	0.020	0.020	0.020	NA
120	Copper		<0.006	0.078	0.047	NA	0.030	0.100	0.100	NA
121	Cyanide	1,2	ND	ND	ND	NA	<0.005	0.001	0.001	NA
122	Lead	0,1	<0.02	<0.02	<0.02	NA	<0.02	0.100	0.100	NA
123	Mercury	12,0	0.0060	110	0.06	NA	0.100	0.800	0.800	NA
124	Nickel	1,0	<0.005	<0.005	<0.005	NA	<0.005	0.010	0.050	NA
125	Selenium		ND	ND	0.08	NA	ND	0.080	ND	NA
126	Silver	6,0	<0.001	0.192	0.036	NA	<0.001	0.010	0.020	NA
127	Thallium		ND	ND	ND	NA	ND	ND	ND	NA
128	Zinc	13,2	0.170	21.0	0.226	NA	0.200	10	40	NA
129	2,3,7,8 TCDD (Dioxin)		NA	NA	NA	NA	NA	NA	NA	NA
130	Xylenes		NA	NA	NA	NA	NA	NA	NA	NA
131	Alkyl Epoxides		NA	NA	NA	NA	NA	NA	NA	NA
	Aluminum	-,-	0.068	0.387	0.217	NA	<0.09	3.00	2.00	NA
	Ammonia	-,-	NA	NA	NA	NA	0.12	11.3	1.81	NA
	Barium	-,-	0.026	0.029	0.358	NA	<0.006	<0.006	<0.006	NA
	Boron	-,-	<0.05	0.316	0.321	NA	<0.08	<0.08	<0.08	NA
	Calcium	-,-	<5.0	<5.0	<5.0	NA	66.0	25.0	14.0	NA
	Cobalt	-,-	<0.005	<0.005	<0.005	NA	<0.002	0.003	0.004	NA
	Fluoride	-,-	1.10	2.65	1.90	NA	0.13	0.44	0.23	NA
	Gold	-,-	ND	ND	ND	NA	ND	ND	ND	NA
	Iron	-,-	0.17	2.06	62.8	NA	<0.1	0.50	0.30	NA
	Magnesium	-,-	2.600	1.50	1.90	NA	30.00	5.90	3.10	NA
	Manganese	-,-	<0.005	0.45	.377	NA	<0.006	2.00	0.80	NA
	Molybdenum	-,-	<0.005	0.015	<0.005	NA	<0.006	0.04	0.02	NA
	Oil and Grease	-,-	3.3	6.00	3.7	NA	1.0	8.00	8.00	NA
	Phenols (Total)	-,-	0.018	0.110	0.180	NA	ND	ND	0.001	NA
	Phosphorus	-,-	ND	1.73	1.54	NA	0.11			NA
	Sodium	-,-	18.80	1570	1580	NA	4.20	410	260	NA
	Strontium	-,-	NA	NA	NA	NA	NA			NA
	TSS	-,-	ND	270	38.0	NA	5.0	428	476.6	NA
	Tin	-,-	<0.005	<0.005	<0.005	NA	<0.008	0.07	0.05	NA
	Titanium	-,-	<0.015	<0.015	<0.015	NA	<0.006	0.02	0.01	NA
	Vanadium	-,-	<0.012	<0.12	<0.12	NA	<0.002	<0.002	0.004	NA
	Yttrium	-,-	<0.016	<0.16	<0.16	NA	<0.002	<0.002	0.003	NA

TABLE V-7
SCREENING ANALYSIS RESULTS (CONT.)
ZINC SUBCATEGORY

DCP Data KTBP,BTBP	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Effluent Conc. mg/1	Analysis Blank Conc. mg/1	Plant Influent Conc. mg/1	Raw Waste Conc. mg/1	Effluent Conc. mg/1	Analysis Blank Conc. mg/1

ND	Not detected
NA	Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analysis were not finalized for these parameters).
KTBP	Known to be present indicated by number of plants.
BTBP	Believed to be present indicated by number of plants.
-,-	Not investigated in DCP survey.
*	Indicates less than .01 mg/1.
**	Indicates less than .005 mg/1.

TABLE V-8
VERIFICATION PARAMETERS

	PARAMETERS	CADMIUM SUBCATEGORY	CALCIUM SUBCATEGORY	LEAD SUBCATEGORY	LECLANCHE SUBCATEGORY	LITHIUM SUBCATEGORY	MAGNESIUM SUBCATEGORY	ZINC SUBCATEGORY
11	1,1,1-Trichlorethane			X				X
13	1,1-Dichlorethane							X
23	Chloroform			X				
29	1,1-Dichloroethylene							X
30	1,2 Trans-dichloroethylene							X
38	Ethylbenzene							X
44	Methylene Chloride	X		X				X
55	Naphthalene			X				X
64	Pentachlorophenol							X
65	Phenol			X				
66	Bis(2-ethyl hexyl)Phthalate			X				
67	Butyl Benzyl Phthalate			X				
68	Di-N-butyl Phthalate			X				
69	Di-N-octyl Phthalate			X				
70	Diethyl Phthalate				X			X
78	Anthracene			X				
81	Phenanthrene			X				
84	Pyrene			X				
85	Tetrachloroethylene							X
86	Toluene							X
87	Trichloroethylene	X						X
114	Antimony			X	X			X
115	Arsenic			X	X			X
118	Cadmium	X		X	X			X
119	Chromium	X		X	X			X
120	Copper			X	X			X
121	Cyanide	X						X
122	Lead	X		X	X			X
123	Mercury	X		X	X			X
124	Nickel	X		X	X			X
125	Selenium				X			X
126	Silver			X				X
128	Zinc	X		X	X			X
	Aluminum							X
	Ammonia	X						X
	Calcium		(X)					
	Cobalt	X						
	Iron			X				X
	Lithium					(X)		
	Magnesium						(X)	
	Manganese				X			X
	Phenols (Total)	X	(X)	X	X	(X)	(X)	X
	Strontium	X		X	X			
	Oil and Grease			X				X
	TSS (Total Suspended Solids)	X	(X)	X	X	(X)	(X)	X
	pH	X	(X)	X	X	(X)	(X)	X

(X)   Tentative

TABLE V-9
CADMIUM SUBCATEGORY PROCESS ELEMENTS
(Reported Manufacture)

	Anodes		
Cathodes	Cadmium Pasted and Pressed Powder	Cadmium Electrodeposited	Cadmium Impregnated
Mercuric Oxide Powder Pressed	X		
Silver Powder Pressed	X		
Nickel Powder Pressed	X		
Nickel Electrodeposited			X
Nickel Impregnated	X	X	X

Ancillary Operations			
Cell Wash	X		
Electrolyte Preparation	X		
Floor and Equipment Wash	X		
Employee Wash	X		
Cadmium Powder Production	X		
Silver Powder Production	X		
Nickel Hydroxide Production	X		
Cadmium Hydroxide Production	X		

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TABLE V-10

CADMIUM SUBCATEGORY EFFLUENT FLOW RATES
FROM INDIVIDUAL FACILITIES

PLANT ID	FLOW RATE 1/day
A	15700
B	>450000
C	145000
D	>450000
E	0
F	54500
G	3780
H	0
I	1890
J	67000

TABLE V-11
NORMALIZED DISCHARGE FLOWS
CADMIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (1/kg)	Median Discharge (1/kg)	Production Weighted Mean Raw Waste (1/kg)	Total Raw Waste Volume (1/yr)	Production Normalizing Parameter
Anodes					
Pasted & Pressed Powder	2.7	1.0	4.63	9.5×10^5	Weight of Cadmium in Anode
Electrodeposited	697.	697.	690.	8.0×10^7	Weight of Cadmium in Anode
Impregnated	998.	998.	960.	1.7×10^8	Weight of Cadmium in Anode
Cathodes					
Nickel Electrode-Posited	569.	569.	569.	6.8×10^5	Weight of Applied Nickel
Nickel Impregnated	1640.	1720.	1140.	2.6×10^8	Weight of Applied Nickel
Ancillary Operations					
Cell Wash	4.93	3.3	3.67	4.7×10^6	Weight of Cells Produced
Electrolyte Preparation	0.08	0.08	0.068	3.7×10^4	Weight of Cells Produced
Floor Wash	12.0	2.4	28.0	7.6×10^6	Weight of Cells Produced
Employee Wash	1.5	1.5	1.5	6.8×10^4	Weight of Cells Produced
Cadmium Powder Production	65.7	65.7	65.7	2.7×10^7	Weight of Cadmium Used
Silver Powder	21.2	21.2	21.2	8.0×10^5	Weight of Silver Powder Produced
Cadmium Hydroxide Production	0.9	0.9	5.15	1.6×10^8	Weight of Cadmium Used
Nickel Hydroxide Production	110.	110.	417.	1.7×10^8	Weight of Nickel Used

TABLE V-12
CADMIUM SUBCATEGORY EFFLUENT QUALITY
(FROM DCP'S)

PLANT ID NO.	TOTAL DISCHARGE FLOW l/hr (gal/hr)		pH	Oil&Grease (mg/l)	TSS (mg/l)	Cd (mg/l)	Co (mg/l)	Ni (mg/l)	Ag (mg/l)	Zn (mg/l)
A	114	(30)				1.1		6.7		
B	114,000 *	(30000)				0.01		0.034		
C	27250	(7200)	7-14			8.1		18.5		
D	33160*	(8760)	12.4	3	150	41		46		
E	23	(6.1)				0.1		<0.08	<0.02	
F	7880	(2081)	7.5			0.04		0.09		
G +	4630	(1220)				0.26	0.08	0.54		
G ++	7040	(1860)						0.34		
H	49500					3.73		3.06		75

* Combined discharge includes wastewater from other subcategories

+ Effluent from pH adjustment and clarification

++ Effluent from ion exchange

TABLE V-13

POLLUTANT CONCENTRATIONS IN CADMIUM
PASTED AND PRESSED POWDER
ANODE ELEMENT WASTE STREAMS

POLLUTANT	mg/l DAYS		
	1	2	3
Temperature (Deg C)	29.0	29.0	31.0
44 Methylene chloride	0.00	0.00	0.00
87 Trichloroethylene	0.00	0.00	0.00
118 Cadmium	285.	365.	151.
119 Chromium, Total	0.01	0.00	0.00
Chromium, Hexavalent	0.00	0.00	0.00
121 Cyanide, Total	0.10	0.00	9.45
Cyanide, Amn. to Chlor.	0.10	0.00	9.40
122 Lead	0.05	0.00	0.02
123 Mercury	0.00	0.00	0.00
124 Nickel	40.5	2.78	13.5
128 Zinc	0.53	0.35	0.35
Ammonia	2.90	0.67	1.15
Cobalt	0.00	0.00	0.00
Phenols, Total	0.04	0.01	0.06
Oil & Grease	5.00	1960.	500.
Total Suspended Solids	808.	1040.	1270.
pH, minimum	10.0	9.6	9.0
pH, maximum	10.0	9.6	9.0

NOTE: VALUES IN ALL SAMPLING TABLES
HAVE BEEN ROUNDED TO TWO DECIMAL
PLACES FOR DRAFT REPORT

TABLE V-14

POLLUTANT MASS LOADINGS IN THE CADMIUM PASTED
AND PRESSED POWDER ANODE ELEMENT
WASTE STREAMS

POLLUTANT	mg/kg DAYS		
	1	2	3
Flow (l/kg)	1.53	1.78	2.68
Temperature (Deg C)	29.0	29.0	31.0
44 Methylene chloride	0.00	0.00	0.00
87 Trichloroethylene	0.00	0.00	0.00
118 Cadmium	437.	650.	405.
119 Chromium, Total	0.00	0.00	0.00
Chromium, Hexavalent	0.00	0.00	0.00
121 Cyanide, Total	0.16	0.00	25.3
Cyanide, Amn. to Chlor.	0.15	0.00	25.2
122 Lead	0.08	0.00	0.05
123 Mercury	0.00	0.00	0.00
124 Nickel	62.1	4.95	36.2
128 Zinc	0.81	0.62	0.94
Ammonia	4.45	1.19	3.08
Cobalt	0.00	0.00	0.00
Phenols, Total	0.06	0.02	0.17
Oil & Grease	7.67	3490.	1340.
Total Suspended Solids	1240.	1850.	3400.
pH, minimum	10.0	9.6	9.0
pH, maximum	10.0	9.6	9.0

Table V-15

POLLUTANT CONCENTRATIONS IN THE CADMIUM
ELECTRODEPOSITED ANODE ELEMENT
WASTE STREAMS

	POLLUTANT	1	mg/l DAYS 2	3
	Temperature (Deg C)	24.6	21.6	24.7
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	108.	130.	46.2
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
121	Cyanide, Total	0.02	0.02	0.02
	Cyanide, Amn. to Chlor.	I	I	I
122	Lead	0.00	0.00	0.00
123	Mercury	0.00	0.00	0.00
124	Nickel	0.08	0.08	0.05
128	Zinc	0.01	0.01	0.00
	Ammonia	2.27	2.49	4.07
	Cobalt	0.00	0.00	0.00
	Phenols, Total	0.01	0.01	0.01
	Oil & Grease	5.05	5.09	5.48
	Total Suspended Solids	188.	178.	14.9
	pH, minimum	2.9	4.5	3.7
	pH, maximum	11.9	11.8	11.7

I - Interference

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Table V-16

POLLUTANT MASS LOADINGS IN THE CADMIUM ELECTRODEPOSITED ANODE ELEMENT WASTE STREAMS

	POLLUTANT	mg/kg DAYS		
		1	2	3
	Flow (1/kg)	691.	697.	697.
	Temperature (Deg C)	24.6	21.6	24.7
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.07	0.07	0.07
118	Cadmium	74700.	90200.	32200.
119	Chromium, Total	0.00	0.42	0.09
	Chromium, Hexavalent	0.00	0.00	0.00
121	Cyanide, Total	14.3	14.1	16.5
	Cyanide, Amn. to Chlor.	I	I	I
122	Lead	0.00	0.00	0.07
123	Mercury	0.41	0.21	0.39
124	Nickel	55.3	58.3	33.6
128	Zinc	6.04	4.48	1.54
	Ammonia	1570.	1730.	2830.
	Cobalt	0.00	0.00	0.00
	Phenols, Total	8.24	8.29	8.29
	Oil & Grease	3490.	3550.	3820.
	Total Suspended Solids	130000.	124000.	10400.
	pH, minimum	2.9	4.5	3.7
	pH, maximum	11.9	11.8	11.7

I - Interference

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Table V-17

POLLUTANT CONCENTRATIONS AND MASS
LOADINGS IN THE CADMIUM IMPREGNATED
ANODE ELEMENT WASTE STREAMS

	POLLUTANT	mg/l DAYS 2	3	mg/kg DAYS 2	3
	Flow (1/kg)			800.3	1283.9
	Temperature (Deg C)	21.6	14.2	21.6	14.2
44	Methylene chloride	0.00	0.00	0.00	0.00
87	Trichloroethylene	*	0.00	0.00	0.00
118	Cadmium	63.3	0.11	50700.	141.
119	Chromium, Total	0.19	0.10	152.	128.
	Chromium, Hexavalent	I	I	I	I
121	Cyanide, Total	0.06	0.02	48.0	25.7
	Cyanide, Amn. to Chlor.	0.02	0.00	16.0	0.00
122	Lead	0.00	0.00	0.00	0.00
123	Mercury	0.001	0.03	0.56	38.5
124	Nickel	3.30	1.20	2640.	1540.
128	Zinc	0.06	0.02	48.0	25.7
	Ammonia	3.20	1.40	2560.	1800.
	Cobalt	0.11	0.04	88.0	51.4
	Phenols, Total	0.03	0.01	24.0	12.8
	Oil & Grease	2.70	2.30	2160.	2930.
	Total Suspended Solids	354.	54.0	283000.	69300.
	pH, minimum	5.2	7.0	5.2	7.0
	pH, maximum	13.5	13.0	13.5	13.0

I - Interference
* - Less than 0.01

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Table V-18

POLLUTANT CONCENTRATIONS IN THE NICKEL
ELECTRODEPOSITED CATHODE ELEMENT
WASTE STREAMS

	POLLUTANT	mg/l DAYS		
		1	2	3
	Temperature (Deg C)	11.0	12.0	10.0
44	Methylene chloride	0.00	*	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	0.05	0.09	0.01
119	Chromium, Total	0.00	0.00	0.01
	Chromium, Hexavalent	0.00	0.00	0.00
121	Cyanide, Total	0.04	0.04	0.01
	Cyanide, Amn. to Chlor.	0.04	0.02	0.00
122	Lead	0.00	0.00	0.00
123	Mercury	0.02	0.00	0.03
124	Nickel	1.98	6.01	1.55
128	Zinc	0.00	0.00	0.00
	Ammonia	0.00	0.00	0.00
	Cobalt	0.00	0.25	0.05
	Phenols, Total	0.01	0.04	0.01
	Oil & Grease	1.00	2.00	2.00
	Total Suspended Solids	0.00	5.00	0.00
	pH, minimum	7.1	5.2	7.0
	pH, maximum	7.1	5.8	7.2

* Less than 0.01

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Table V-19

POLLUTANT MASS LOADINGS IN THE NICKEL
ELECTRODEPOSITED CATHODE ELEMENT
WASTE STREAMS

POLLUTANT	mg/kg DAYS		
	1	2	3
Flow (l/kg)	97.7	416.	1180.
Temperature (Deg C)	11.0	12.0	10.0
44 Methylene chloride	0.00	0.04	0.00
87 Trichloroethylene	0.00	0.00	0.00
118 Cadmium	4.69	37.5	15.2
119 Chromium, Total	0.00	0.00	8.20
Chromium, Hexavalent	0.00	0.00	0.00
121 Cyanide, Total	4.10	16.7	12.8
Cyanide, Amn. to Chlor.	4.10	6.70	0.00
122 Lead	0.00	0.00	0.00
123 Mercury	1.56	0.00	37.3
124 Nickel	193.	2500.	1810
128 Zinc	0.00	0.00	0.00
Ammonia	0.00	0.00	0.00
Cobalt	0.00	104.	61.9
Phenols, Total	0.59	17.5	16.3
Oil & Grease	97.7	833.	2330.
Total Suspended Solids	0.00	2080.	0.00
pH, minimum	7.1	5.2	7.0
pH, maximum	7.1	5.8	7.2

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Table V-20

POLLUTANT CONCENTRATIONS IN THE NICKEL
IMPREGNATED CATHODE ELEMENT
WASTE STREAMS

mg/l

	POLLUTANT	PLANT A			PLANT C DAYS			PLANT D		PLANT B	
		1	2	3	1	2	3	1	2	1	2
	Temperature (Deg C)	28.6	16.7	30.2	51.5	38.7	43.9	16.0	16.0	71.9	69.9
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	Trichloroethylene	*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
118	Cadmium	79.2	25.5	10.7	0.02	0.04	0.14	0.03	*	13.4	0.77
119	Chromium, Total	0.18	0.09	0.05	0.05	0.14	0.11	0.00	0.00	*	*
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	I	I	0.00	0.00	0.00	0.00
121	Cyanide, Total	0.03	0.03	0.02	0.05	0.07	0.01	0.00	0.00	0.29	0.05
	Cyanide, Amn. to Chlor.	0.02	0.02	0.02	0.05	*	0.00	0.00	0.00	0.00	0.00
122	Lead	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
123	Mercury	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
124	Nickel	514.	189.	120.	21.1	9.20	44.7	59.0	1.96	199.	14.5
128	Zinc	0.05	0.03	0.06	0.12	0.34	0.03	0.22	0.15	0.30	0.71
	Ammonia	8.64	9.39	9.03	8.50	8.10	8.50	NA	NA	86.6	18.9
	Cobalt	0.00	0.00	0.00	0.26	0.21	1.30	4.70	0.08	0.10	0.00
	Phenols, Total	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.00	0.03	0.09
	Oil & Grease	27.6	7.44	6.16	0.99	1.30	6.90	2.40	3.00	6.10	6.06
	Total Suspended Solids	1163.	342.	185.	2690.	644.	92.5	96.0	28.0	87.9	64.8
	pH, minimum	4.1	4.0	5.2	9.7	6.5	8.0	7.7	8.5	1.0	1.0
	pH, maximum	13.1	13.0	12.8	12.0	10.0	11.5	10.9	10.5	14.0	14.0

I - Interference
NA - Not Analyzed
* - Less than 0.01

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Table V-21

POLLUTANT MASS LOADINGS IN THE NICKEL
IMPREGNATED CATHODE ELEMENT WASTE STREAMS

		PLANT A			mg/kg PLANT C DAYS			PLANT D		PLANT B	
	POLLUTANTS	1	2	3	1	2	3	1	2	1	2
	Flow (l/kg)	1820.	1630.	1621.	1360.	2000.	1530.	2000.	4000.	228.	197.
	Temperature (Deg C)	28.6	16.7	30.2	51.5	38.7	43.9	16.0	16.0	71.9	69.9
44	Methylene chloride	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.04	0.16	0.00	0.00	0.00	0.20	0.40	0.00	0.00
118	Cadmium	41400.	144000.	17400.	27.1	78.2	228.	51.7	15.9	3050.	152.
119	Chromium, Total	139.	323.	72.9	67.8	274.	179.	0.00	0.00	0.44	0.38
	Chromium, Hexavalent	0.00	0.00	0.00	0.0	I	I	0.00	0.00	0.00	0.00
121	Cyanide, Total	54.1	45.5	37.2	67.8	137.	13.0	0.00	0.00	65.2	10.1
	Cyanide, Amn. to Chlor.	26.1	33.3	28.4	67.8	15.6	0.00	0.00	0.00	0.00	0.00
122	Lead	18.2	0.00	0.00	0.00	20.0	0.00	0.00	0.00	0.00	0.00
123	Mercury	18.3	1.48	0.60	1.40	0.59	32.5	0.00	0.00	0.00	0.00
124	Nickel	307000.	934000.	195000.	28600.	18000.	72700.	117000.	7800.	45400.	2850.
128	Zinc	44.0	82.1	90.0	163.	644.	48.8	438.	597.	69.2	140.
	Ammonia	15300.	15700.	14600.	11500.	15800.	5690.			19700.	3730.
	Cobalt	0.00	0.00	0.00	353.	410.	2110.	9350.	322.	23.0	0.12
	Phenols, Total	8.99	12.3	9.24	10.9	39.1	16.3	29.8	0.00	5.68	16.9
	Oil & Grease	12100.	50200.	9990.	1340.	2540.	11200.	4780.	11900.	1390.	1200.
	Total Suspended Solids	556000.	2110000.	300000.	3640000.	1300000.	150000.	191000.	111000.	20000.	12800.
	pH, minimum	4.0	4.1	5.2	9.7	6.5	8.0	7.7	8.5	1.0	1.0
	pH, maximum	13.0	13.1	12.8	12.0	10.0	11.5	10.9	10.5	14.0	14.0

I - Interference

Table V-22

STATISTICAL ANALYSIS (mg/l) OF THE NICKEL
IMPREGNATED CATHODE ELEMENT WASTE STREAMS

	POLLUTANT	MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL.	# ZEROS	# PTS.
	Temperature (Deg C)	16.0	71.9	38.4	34.5	10	0	10
44	Methylene chloride	0.00	0.00	0.00	0.00	0	10	10
87	Trichloroethylene	0.00	*	0.00	0.00	0	10	10
118	Cadmium	0.00	79.2	13.0	0.46	10	0	10
119	Chromium, Total	0.00	0.18	0.06	0.05	8	2	10
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	8	8
121	Cyanide, Total	0.00	0.29	0.05	0.03	8	2	10
	Cyanide, Amn. to Chlor.	0.00	0.05	0.01	0.00	5	5	10
122	Lead	0.00	0.01	0.00	0.00	10	8	10
123	Mercury	0.00	0.02	0.00	0.00	5	5	10
124	Nickel	1.96	514.	117.	51.9	10	0	10
128	Zinc	0.03	0.71	0.20	0.14	10	0	10
	Ammonia	3.50	86.6	19.1	8.60	8	0	8
	Cobalt	0.00	4.70	0.67	0.09	7	3	10
	Phenols, Total	0.00	0.09	0.02	0.01	9	1	10
	Oil & Grease	0.99	27.6	6.80	6.10	10	0	10
	Total Suspended Solids	28.0	2690.	539.	141.	10	0	10
	pH, minimum	1.0	9.7	5.6	5.9	10	0	10
	pH, maximum	10.0	14.0	12.2	12.4	10	0	10

* - Less than 0.01
Number of values may include concentrations less than 0.005 shown
as 0.00 on tables.

Table V-23

STATISTICAL ANALYSIS (mg/kg) OF THE NICKEL
IMPREGNATED CATHODE ELEMENT WASTE STREAMS

	POLLUTANT	MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (1/kg)	197.	3980.	1661.	1630.
	Temperature (Deg C)	16.0	71.9	38.3	34.4
44	Methylene Chloride	0.00	0.01	0.00	0.00
87	Trichloroethylene	0.00	0.40	0.08	0.00
118	Cadmium	15.9	144000.	20600.	190.
119	Chromium, Total	0.00	323.	106.	70.4
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
121	Cyanide, Total	0.00	137.	43.0	41.4
	Cyanide, Amn. to Chlor.	0.00	67.8	17.1	7.80
122	Lead	0.00	16.9	2.93	0.00
123	Mercury	0.00	32.5	5.50	0.59
124	Nickel	2850.	934000.	173000.	59000.
128	Zinc	44.0	644.	232.	115.
	Ammonia	3730.	19700.	12800.	15000.
	Cobalt	0.00	9350.	1260.	173.
	Phenols, Total	0.00	39.1	14.9	11.6
	Oil & Grease	1200.	50200.	10700.	7380.
	Total Suspended Solids	12800.	3640000.	840000.	246000.
	pH, minimum	1.0	9.7	5.6	5.9
	pH, maximum	10.0	14.0	12.2	12.4

Table V-24

POLLUTANT CONCENTRATIONS IN THE FLOOR AND EQUIPMENT WASH ELEMENT WASTE STREAMS

mg/l

POLLUTANT

	Temperature (Deg C)	16.0
44	Methylene chloride	NA
87	Trichloroethylene	NA
118	Cadmium	29.2
119	Chromium, Total	0.08
	Chromium, Hexavalent	0.00
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.00
123	Mercury	0.00
124	Nickel	9.08
128	Zinc	12.9
	Ammonia	NA
	Cobalt	5.04
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	NA
	pH, minimum	7.9
	pH, maximum	7.9

NA - Not Analyzed

Table V-25

POLLUTANT MASS LOADINGS IN THE FLOOR AND
EQUIPMENT WASH ELEMENT WASTE STREAMS

	POLLUTANT	mg/kg
	Flow (1/kg)	0.25
	Temperature (Deg C)	16.0
44	Methylene chloride	NA
87	Trichloroethylene	NA
118	Cadmium	7.18
119	Chromium, Total	0.02
	Chromium, Hexavalent	0.00
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.00
123	Mercury	0.00
124	Nickel	2.23
128	Zinc	3.17
	Ammonia	NA
	Cobalt	1.24
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	NA
	pH, minimum	7.9
	pH, maximum	7.9

NA - Not Analyzed

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Table V-26

POLLUTANT CONCENTRATIONS IN EMPLOYEE WASH ELEMENT WASTE STREAMS

	POLLUTANT	1	mg/l DAYS 2	3
	Temperature (Deg C)	31.0	32.0	32.0
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	0.00	0.13	0.08
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
121	Cyanide, Total	0.00	0.03	0.04
	Cyanide, Amn. to Chlor.	0.00	0.03	0.04
122	Lead	0.00	0.00	0.00
123	Mercury	0.00	0.00	0.00
124	Nickel	0.00	0.13	0.26
128	Zinc	0.19	0.24	0.05
	Ammonia	0.00	0.00	0.00
	Cobalt	0.00	0.00	0.00
	Phenols, Total	0.01	0.01	0.00
	Oil & Grease	1.0	212.	288.
	Total Suspended Solids	0.00	280.	312.
	pH, minimum	7.3	6.8	7.9
	pH, maximum	7.3	6.8	7.9

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Table V-27

POLLUTANT MASS LOADINGS IN EMPLOYEE WASH
ELEMENT WASTE STREAMS

	POLLUTANT	1	mg/kg DAYS 2	3
	Flow (1/kg)	1.48	1.48	1.48
	Temperature (Deg C)	31.0	32.0	32.0
44	Methylene chloride	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
118	Cadmium	0.003	0.19	0.11
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
121	Cyanide, Total	0.00	0.04	0.05
	Cyanide, Amn. to Chlor.	0.00	0.04	0.05
122	Lead	0.00	0.00	0.00
123	Mercury	0.00	0.00	0.00
124	Nickel	0.00	0.19	0.38
128	Zinc	0.28	0.35	0.07
	Ammonia	0.00	0.00	0.00
	Cobalt	0.0	0.00	0.00
	Phenols, Total	0.01	0.02	0.00
	Oil & Grease	1.48	313.	425.
	Total Suspended Solids	0.00	413.	460.
	pH, minimum	7.3	6.8	7.9
	pH, maximum	7.3	6.8	7.9

TABLE V-28

MEAN CONCENTRATIONS AND POLLUTANT
MASS LOADINGS IN THE CADMIUM
POWDER ELEMENT WASTE STREAMS

	POLLUTANT	Mean (mg/l)	Mean (mg/kg)
	Flow (l/kg)		65.7
	Temperature (Deg C)	21.9	21.9
44	Methylene chloride	0.00	0.00
87	Trichloroethylene	0.00	0.00
118	Cadmium	117.	7710.
119	Chromium, Total	0.004	0.26
	Chromium, Hexavalent	0.00	0.00
121	Cyanide, Total	0.03	1.70
	Cyanide, Amn. to Chlor.	0.00	0.00
122	Lead	0.00	0.00
123	Mercury	0.01	0.53
124	Nickel	0.06	3.90
128	Zinc	4270.	281000.
	Ammonia	5.20	342.
	Cobalt	0.00	0.00
	Phenols, Total	0.02	1.30
	Oil & Grease	4.40	289.
	Total Suspended Solids	17.5	1150.
	pH, minimum	1.3	1.3
	pH, maximum	3.3	3.3

Table V-29

CADMIUM SUBCATEGORY - STATISTICAL ANALYSIS OF TOTAL
RAW WASTE CONCENTRATIONS
(mg/l)**

Pollutants		Minimum	Maximum	Mean	Median	No. of Positive Values	No. of Zeros
Temperature		14.0	66.8	29.6	25.4	12	0
44	Methylene Chloride	0.00	0.03	*	*	6	6
87	Trichloroethylene	0.00	*	*	*	9	3
118	Cadmium	0.00	230	41.9	18.3	11	1
119	Chromium (total)	0.00	0.76	0.20	0.09	12	0
	Chromium (hexavelent)	0.00	0.00	0.00	0.00	0	12
121	Cyanide (total)	0.00	0.26	0.07	0.02	9	2
	Cyanide (amenable)	0.00	0.24	0.03	0.00	8	3
122	Lead	0.00					
123	Mercury	0.00	0.03	0.00	0.00	8	4
124	Nickel	0.57	281.	61.0	19.2	12	0
126	Silver+	0.00	23.9	8.47	9.98	3	1
128	Zinc	0.00	3310.	391.	0.15	11	1
	Ammonia	1.94	77.7	14.8	6.69	9	0
	Cobalt	0.00	1.57	0.39	0.05	7	5
	Phenols (total)	0.00	0.08	0.02	0.01	10	1
	Oil and Grease	0.80	17.4	6.62	5.73	11	0
	Total Suspended Solids	13.0	2290.	323.	64.2	12	0
	pH Minimum	1.0	7.1	3.4	2.6	12	0
	pH Maximum	2.5	14.0	11.6	12.9	12	0

** Values of 0.00 in table with positive values indicated reflect measured values of
   pollutant in some samples, but calculated total raw waste concentration less than 0.005 mg/l.

+ Not a cadmium subcategory verification parameter, analyzed only where silver cathodes produced.

* Less than 0.01.

Table V-30

EFFLUENT CHARACTERISTICS FROM CALCIUM SUBCATEGORY
MANUFACTURING OPERATIONS - DCP DATA

Flow Rate l/hr (gal/hr)	Cd mg/l	Ba mg/l	Cr mg/l
1385. (366)*	0.01	20.0	0.20

* Intermittent flow, average is $\leq$45 l/hr (2 gal/hr) on a monthly
basis.

TABLE V-30 A
NORMALIZED DISCHARGE FLOWS
CALCIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Production Weighted Mean Raw Waste (l/kg)	Total Raw Waste Volume (l/yr)	Production Normalizing Parameter
Heat Paper Manufacture	276	24.1	16.9	1.3×10^5	Weight of Reactants
Cell Leak Testing	0.014	0.014	0.010	200	Weight of Cells Produced.

Table V-31

NORMALIZED DISCHARGE FLOWS
LEAD SUBCATEGORY ELEMENTS[1]/

Element	Mean Discharge (1/kg)	Median Discharge (1/kg)	No. of Plants Represented in Data
Anodes and Cathodes			
Leady Oxide Production	0.21	0.0	34
Paste Preparation and Application	0.57	0.0	95
Curing	0.01	0.0	89
Closed Formation (In Case)			
Single Fill	0.09	0.0	40
Double Fill	1.26	0.31	30
Fill and Dump	1.73	0.83	11
Open Formation (Out of Case)			
Dehydrated	18.4	9.0	35
Wet	4.77	0.0	7
Ancillary Operations			
Battery Wash	1.28	0.72	60
Floor Wash	0.41	0.49	5
Battery Repair	0.17	0.17	1

[1]/ Production normalizing parameter is total weight of lead used.

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Table V-32

OBSERVED DISCHARGE FLOW RATES
FOR EACH PLANT IN LEAD SUBCATEGORY

Plant Number	Observed Flow Rate (1/hr)	Plant Number	Observed Flow Rate (1/hr)
107	1699	311	20900
110	4883	320	34450
112	2952	321	0.0
122	11640	331	2566
132	0.4	342	61910
133	NA	346	0.0
135	0.0	349	7843
138	329	350	NA
144	0.0	356	0.0
146	2725	358	6699
147	8	361	NA
152	9278	366	0.0
155	NA	370	NA
158	0.0	371	2184
170	0.0	372	0.0
173	57	374	454
178	0.0	377	0.0
179	8	382	2763
182	NA	386	7949
184	0.0	387	43671
190	0.0	400	4269
191	37320	402	NA
198	10260	403	NA
207	18850	406	NA
208	NA	421	0.0
212	6813	429	0.0
213	454	430	0.0
226	9312	436	0.0
233	9372	439	29042
237	11360	444	0.0
239	6086	446	6927
242	NA	448	14630
255	NA	450	27252
261	2271	462	2574
269	31385	463	NA
277	15	466	0.0
278	5678	467	0.0
280	NA	469	15
288	NA		
295	0.0	472	2892
299	0.0	480	22210

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TABLE V-32 (CON'T)

OBSERVED DISCHARGE FLOW RATES
FOR EACH PLANT IN LEAD SUBCATEGORY

Plant Number	Observed Flow Rate (1/hr)	Plant Number	Observed Flow Rate (1/hr)
486	NA	705	2725
491	NA	706	0.0
493	NA	714	1590
494	7816	716	NA
495	NA	717	6472
501	11920	721	0.0
503	11128	722	NA
504	0.0	725	0.0
513	1817	730	443
517	0.0	731	2840
520	4542	732	3588
521	0.0	733	NA
522	0.0	738	29080
526	22710	740	NA
529	568	746	0.0
536	NA	765	13073
543	0.0	768	3452
549	47460	771	1363
553	3429	772	11470
572	3274	775	1135
575	2725	777	4315
594	0.0	781	6624
620	NA	785	41640
623	NA	786	5110
634	1533	790	0.0
635	4360	796	0.0
640	22030	811	NA
646	810	814	13110
652	12692	815	598
656	NA	817	0.0
668	0.0	820	3407
672	22500	828	68
677	0.0	832	8327
680	2074	852	16070
681	31794	854	0.0
682	6813	857	4201
683	265	863	11057
685	5450	866	0.0
686	9084	877	18573
690	0.0	880	0.0
704	8849	883	0.0

TABLE V-32 CON'T

OBSERVED DISCHARGE FLOW RATES
FOR EACH PLANT IN LEAD SUBCATEGORY

Plant Number	Observed Flow Rate (1/hr)	Plant Number	Observed Flow Rate (1/hr)
893	2157	963	0.0
901	0.0	964	0.0
917	18849	968	0.0
920	NA	971	0.0
927	0.0	972	23846
936	3634	976	26800
939	NA	978	1226
942	0.0	979	0.0
943	17487	982	10537
947	18400	990	3180
951	1136		

NA - Not Available

Table V-33

EFFLUENT CHARACTERISTICS REPORTED BY PLANTS PRACTICING PH ADJUSTMENT AND SETTLING TECHNOLOGY

Direct/ Indirect	Production Normalized Effluent l/kg	pH	Pollutant Parameter (mg/l)					Paste Recirc.
			O&G	TSS	Fe	Pb	Zn	
D	5.10	6.9		20				
I	1.88					1.1-4.3		X
I	3.15					7.5		
D	8.0					0.4		
I	4.56	7.5				0.5		
I	9.76					1.0		
I	2.01	6.9	8.2	3.7		0.8		
D	6.35	7	4.5	3		0.187		
I	13.32					2.7		X
I	51.9	6.65		1.4	0.2	1.0	0.1	X
D	1.74			4.6		0.28		
I	1.34							X
I	2.57					1.0		
D	5.76			330		0.25		
I	1.58	5.85	26.14	257.7				

Table V-34

EFFLUENT QUALITY DATA FROM PLANTS PRACTICING PH ADJUSTMENT AND FILTRATION

	Direct/ Indirect	Production Normalized Effluent l/kg	pH	O&G	TSS	Fe	Pb	Zn	Paste Recirc
A	I	2.78			0		1.0		
B	D	4.41				0.3	0.05	0.1	X
C	I	43.1					.5	Filter&Settle	
D	I	1.56	7.5				0.3		
E	I	3.46	7.5		0.0				
F	D	9.9					0.47	0.34	
G	I	0.70	11.2				0.25	0.1	

Table V-35

EFFLUENT QUALITY DATA FROM PLANTS PRACTICING PH ADJUSTMENT ONLY

	Direct/ Indirect	Production Normalized Effluent l/kg	pH	O&G	TSS	Fe	Pb	Zn	Paste Recirc
A	I	6.07					29.8		
B	I	22.9					10-15		
C	I	3.73					2.77		X
D	I	81.7					6.0		
E	I	13.5 5.35					27.5		
F	I	51.9	6.65		1.4	.2	1.0		X
G	I	10.1			33			0.4	
H	I	5.02	5.7		32		3.95		
I	I*	26.4					10-15		
J	I	63.3				0	3.0		X
K	I	15.0					26.92	0.24	

* Reports no effluent treatment prior to release to POTW

Table V-36

TOTAL RAW WASTE FOR VISITS
(mg/l)

		PLANT A			PLANT B		
	Temperature (Deg C)	18.2	18.9	18.0	17.0	17.0	17.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.03	0.00	0.00
23	Chloroform	0.00	0.00	0.00	*	0.00	0.00
44	Methylene chloride	*	0.00	0.00	*	0.00	0.00
55	Naphthalene	*	0.01	0.02	*	0.00	0.00
65	Phenol	NA	0.00	NA	*	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	*	0.01	0.14	0.04	0.03
67	Butyl benzyl phthalate	*	0.00	*	0.02	0.00	0.00
68	Di-n-butyl phthalate	0.00	*	*	*	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.14	0.00	0.00
78	Anthracene	0.00	*	*	0.03	0.00	0.00
81	Phenanthrene	0.00	*	*	0.03	0.00	0.00
84	Pyrene	0.00	0.00	0.00	*	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.01	0.00	0.00	0.00
118	Cadmium	0.03	0.00	0.01	0.01	0.00	0.01
119	Chromium, Total	0.12	0.03	0.05	0.01	0.01	0.02
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	NA	NA
120	Copper	0.44	0.28	0.38	0.08	0.09	0.11
122	Lead	6.88	1.43	1.17	13.0	15.4	45.9
123	Mercury	0.00	0.01	0.03	NA	0.00	0.00
124	Nickel	0.12	0.02	0.03	0.00	0.00	0.02
126	Silver	0.00	0.00	0.00	0.03	0.01	0.02
128	Zinc	0.31	0.13	0.19	0.33	0.35	0.38
	Iron	6.64	6.55	5.52	2.00	3.80	4.37
	Phenols, Total	0.02	0.01	0.05	0.01	0.00	0.00
	Strontium	0.02	0.00	0.00	NA	0.00	0.00
	Oil & Grease	49.0	13.0	9.24	36.5	10.6	5.20
	Total Suspended Solids	416.	15.0	16.4	57.8	31.2	52.4
	pH, Minimum	2.0	2.0	2.0	2.2	2.0	1.8
	pH, Maximum	11.9	6.8	5.7	3.6	4.9	3.9

NA-Not Analyzed
*-Less than 0.01

Table V-36 (con't)

TOTAL RAW WASTE FOR VISITS
(mg/1)

		PLANT C			PLANT D			PLANT E
	Temperature (Deg C)	15.3	16.5	16.7	35.1	33.5	28.0	NA
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	*	*	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	*	*	*	0.00
65	Phenol	NA	NA	NA	NA	NA	NA	0.00
66	Bis(2-ethylhexyl)phthalate	0.04	0.01	*	0.03	0.04	0.05	*
67	Butyl benzyl phthalate	0.00	0.00	0.00	*	*	*	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	*	*	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	*	*	*	0.00
78	Anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.09	0.19	0.13
115	Arsenic	0.00	0.00	0.00	0.02	0.00	0.12	NA
118	Cadmium	0.00	0.00	0.00	0.00	0.00	0.00	0.03
119	Chromium, Total	0.10	0.06	0.07	0.67	0.73	3.27	NA
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA	0.00
120	Copper	0.06	0.08	0.05	0.32	0.77	2.50	NA
122	Lead	1.00	1.36	1.45	18.3	15.7	44.9	13.4
123	Mercury	0.00	0.00	0.00	0.00	0.00	0.00	0.05
124	Nickel	0.08	0.04	0.07	0.38	0.51	2.49	NA
126	Silver	0.00	0.00	0.00	0.00	0.00	0.02	0.01
128	Zinc	0.05	0.12	0.19	0.75	1.07	6.80	3.88
	Iron	9.24	15.5	9.41	15.5	20.1	74.0	390.
	Phenols, Total	0.00	0.00	0.00	0.02	0.04	0.03	0.02
	Strontium	0.03	0.03	0.03	0.00	0.00	0.00	0.00
	Oil & Grease	3.10	4.00	3.90	10.3	9.44	16.7	3.00
	Total Suspended Solids	6.00	14.0	5.00	350.1	974.	1300.	184.
	pH, Minimum	2.1	2.0	2.0	2.0	2.0	2.0	NA
	pH, Maximum	2.9	2.4	2.4	12.0	12.0	12.0	NA

NA-Not Analyzed
*-Less than 0.01

Table V-37

LEAD SUBCATEGORY TOTAL RAW WASTE LOADINGS
(mg/kg)

		PLANT A			PLANT B		
	Flow (1/kg)	1.21	1.20	0.71	8.84	9.87	10.3
	Temperature (Deg C)	18.2	18.9	18.0	17.0	17.0	17.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.22	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.02	0.01	0.00	0.01	0.01
65	Phenol	NA	0.00	NA	0.00	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.01	1.19	0.43	0.31
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.15	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	1.24	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.28	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.28	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.01
114	Antimony	0.002	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.004	0.00	0.00	0.00
118	Cadmium	0.03	0.004	0.004	0.07	0.03	0.12
119	Chromium, Total	0.15	0.04	0.03	0.08	0.12	0.18
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	NA	NA
120	Copper	0.53	0.33	0.27	0.73	0.89	1.13
122	Lead	8.31	1.72	0.83	115.	152.	471.
123	Mercury	0.00	0.01	0.02	NA	0.00	0.00
124	Nickel	0.15	0.03	0.02	0.00	0.00	0.21
126	Silver	0.00	0.00	0.00	0.29	0.07	0.15
128	Zinc	0.37	0.16	0.14	2.94	3.46	3.90
	Iron	8.02	7.84	3.89	17.7	37.5	44.9
	Phenols, Total	0.02	0.02	0.04	0.07	0.00	0.00
	Strontium	0.03	0.00	0.00	NA	0.00	0.00
	Oil & Grease	59.2	15.5	6.52	323.	105.	53.4
	Total Suspended Solids	502.	18.0	11.6	511.	308.	538.
	pH, Minimum	2.0	2.0	2.0	2.2	2.0	1.8
	pH, Maximum	11.9	6.8	5.7	3.6	4.9	3.9

NA-Not Analyzed

Table V-37 (CON'T)

LEAD SUBCATEGORY TOTAL RAW WASTE LOADINGS
(mg/kg)

		PLANT C			PLANT D			PLANT E
	Flow (l/kg)	6.68	6.59	6.98	1.35	1.25	0.56	0.22
	Temperature (Deg C)	15.3	16.5	16.7	35.1	33.5	28.0	NA
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	Phenol	NA	NA	NA	NA	NA	NA	0.00
66	Bis(2-ethylhexyl)phthalate	0.25	0.07	0.00	0.04	0.05	0.03	0.00
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.11	0.11	0.03
115	Arsenic	0.00	0.00	0.00	0.03	0.00	0.07	NA
118	Cadmium	0.00	0.00	0.00	0.003	0.01	0.002	0.01
119	Chromium, Total	0.65	0.38	0.47	0.91	0.92	1.84	NA
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA	0.00
120	Copper	0.42	0.51	0.37	0.44	0.97	1.41	NA
122	Lead	6.68	8.96	10.1	24.7	19.6	25.2	2.92
123	Mercury	0.00	0.00	0.00	0.00	0.00	0.00	0.01
124	Nickel	0.52	0.24	0.48	0.52	0.63	1.40	NA
126	Silver	0.00	0.00	0.00	0.001	0.001	0.01	0.002
128	Zinc	0.36	0.79	1.33	1.01	1.34	3.82	0.85
	Iron	61.8	102.	65.7	20.9	25.2	41.6	85.0
	Phenols, Total	0.00	0.00	0.00	0.03	0.05	0.02	0.004
	Strontium	0.18	0.22	0.23	0.00	0.00	0.001	0.00
	Oil & Grease	20.7	26.4	27.2	14.0	11.8	9.36	0.65
	Total Suspended Solids	40.1	92.3	34.9	473.	1220.	731.	40.1
	pH, Minimum	2.1	2.0	2.0	2.0	2.0	2.0	NA
	pH, Maximum	2.9	2.4	2.4	12.0	12.0	12.0	NA

NA-Not Analyzed

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Table V-38

STATISTICAL SUMMARY OF THE LEAD SUBCATEGORY
RAW WASTE
(mg/l)

	POLLUTANTS	Minimum	Maximum	Mean	Median	# Val.	# Zeros	# Pts.
	Temperature (Deg C)	15.3	35.1	17.5	17.5	12	0	12
11	1,1,1-Trichloroethane	*	0.03	*	*	13	0	13
23	Chloroform	0.00	*	*	0.00	6	7	13
44	Methylene chloride	0.00	*	*	*	8	5	13
55	Naphthalene	0.00	0.01	*	*	10	3	13
65	Phenol	0.00	*	*	0.00	1	2	3
66	Bis(2-ethylhexyl)phthalate	*	0.14	0.03	0.03	13	0	13
67	Butyl benzyl phthalate	0.00	0.02	*	*	7	6	13
68	Di-n-butyl phthalate	0.00	*	*	*	8	5	13
69	Di-n-octyl phthalate	0.00	0.14	0.01	0.00	6	7	13
78	Anthracene	0.00	0.03	*	*	7	6	13
81	Phenanthrene	0.00	0.03	*	*	7	6	13
84	Pyrene	0.00	*	*	0.00	5	8	13
114	Antimony	0.00	0.19	0.03	0.00	4	9	13
115	Arsenic	0.00	0.12	0.01	0.00	4	8	12
118	Cadmium	0.00	0.03	0.01	0.00	10	3	13
119	Chromium, Total	0.01	3.27	0.43	0.06	12	0	12
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	5	5
120	Copper	0.05	2.50	0.43	0.19	12	0	12
122	Lead	1.00	45.9	13.8	13.0	13	0	13
123	Mercury	0.00	0.05	0.01	0.00	4	8	12
124	Nickel	0.00	2.49	0.31	0.05	10	2	12
126	Silver	0.00	0.03	0.01	0.00	8	5	13
128	Zinc	0.05	6.80	1.12	0.33	13	0	13
	Iron	2.0	390.	43.3	9.24	13	0	13
	Phenols, Total	0.00	0.05	0.01	0.01	8	5	13
	Strontium	0.00	0.03	0.01	0.00	5	7	12
	Oil & Grease	3.00	49.0	13.4	9.44	13	0	13
	Total Suspended Solids	5.00	1300.	263.	52.4	13	0	13
	pH, Minimum	1.8	2.2	2.0	2.0	12	0	12
	pH, Maximum	2.4	12.0	6.7	5.3	12	0	12

* Less than 0.01

Table V-39

STATISTICAL ANALYSIS OF THE LEAD SUBCATEGORY
TOTAL RAW WASTE LOADINGS
(mg/kg)

	POLLUTANTS	MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (1/kg)	0.22	10.3	4.29	1.35
	Temperature (Deg C)	15.3	35.1	17.5	17.5
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.05	0.00	0.00
65	Phenol	0.00	0.00	0.00	0.00
66	Bis(2-ethylhexyl)phthalate	0.00	1.19	0.19	0.04
67	Butyl benzyl phthalate	0.00	0.15	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	1.24	0.10	0.00
78	Anthracene	0.00	0.28	0.00	0.00
81	Phenanthrene	0.00	0.28	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.11	0.02	0.00
115	Arsenic	0.00	0.07	0.01	0.00
118	Cadmium	0.00	0.12	0.02	0.004
119	Chromium, Total	0.03	1.84	0.48	0.28
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.27	1.41	0.67	0.52
122	Lead	0.83	471.	65.2	10.1
123	Mercury	0.00	0.02	0.003	0.00
124	Nickel	0.00	1.40	0.35	0.22
126	Silver	0.00	0.29	0.04	0.001
128	Zinc	0.14	3.90	1.57	1.01
	Iron	3.89	102.	40.2	37.5
	Phenols, Total	0.00	0.07	0.02	0.02
	Strontium	0.00	0.23	0.06	0.00
	Oil & Grease	0.65	323.	51.7	20.7
	Total Suspended Solids	11.6	1220.	348.	308.
	pH, Minimum	1.8	2.2	2.0	2.0
	pH, Maximum	2.4	12.0	6.7	5.3

NA-Not Analyzed

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Table V-40

LEAD SUBCATEGORY CHARACTERISTICS OF INDIVIDUAL PROCESS WASTES

POLLUTANTS	PASTING		Wet Batteries Closed Formation		Damp Batteries Closed Formation		Dehydrated Batteries Open Formation		BATTERY WASH
Flow (l/kg)			0.22		0.45		1.30	13.9	0.62	
	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/i	mg/kg
Temperature (Deg C)	29.0	29.0	18.5	18.5	19.3	19.3	49.2	49.2	23.0	23.0
11 1,1,1-Trichloroethane	*	0.00	0.00	0.00	0.00	0.00	*	0.00	0.00	0.00
23 Chloroform	*	0.00	0.00	0.00	0.00	0.00	*	0.00	0.00	0.00
44 Methylene chloride	0.00	0.00	*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55 Naphthalene	*	0.00	0.00	0.00	0.00	0.00	*	0.00	0.01	0.01
65 Phenol	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
66 Bis(2-ethylhexyl)phthalate	*	0.00	*	0.00	*	0.00	0.06	0.92	0.02	0.01
67 Butyl benzyl phthalate	0.00	0.00	*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68 Di-n-butyl phthalate	*	0.00	*	0.00	*	0.00	*	0.00	0.00	0.00
69 Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78 Anthracene	*	0.00	0.00	0.00	0.00	0.00	*	0.00	0.00	0.00
81 Phenanthrene	*	0.00	0.00	0.00	0.00	0.00	*	0.00	0.00	0.00
84 Pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115 Arsenic	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.00
118 Cadmium	0.01	0.00	0.01	0.002	0.01	0.01	0.00	0.05	0.00	0.001
119 Chromium, Total	0.01	0.00	0.05	0.02	0.12	0.13	0.05	0.66	0.62	0.45
Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
120 Copper	0.10	0.02	0.17	0.08	0.40	0.49	0.04	0.58	0.45	0.29
122 Lead	280.	16.3	0.96	0.50	1.84	2.33	7.66	109.	7.4	5.0
123 Mercury	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
124 Nickel	0.01	0.001	0.02	0.01	0.09	0.10	0.11	1.54	0.06	0.05
126 Silver	0.18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
128 Zinc	0.51	0.05	0.08	0.04	0.14	0.16	0.34	4.76	0.53	0.38
Iron	2.03	0.25	5.10	2.03	6.88	7.97	1.57	20.5	16.8	12.1
Phenols, Total	0.08	0.01	0.02	0.01	0.02	0.03	0.01	0.16	0.02	0.01
Strontium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil & Grease	35.0	2.22	1.10	0.52	1.25	1.64	4.05	60.0	16.0	8.9
Total Suspended Solids	11000.	1320.	6.00	3.12	10.5	12.7	4.50	72.5	81.5	44.3
pH, Minimum	6.7	6.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
pH, Maximum	8.9	8.9	2.6	2.6	3.9	3.9	4.8	4.8	9.9	9.9

NA-Not Analyzed

Table V-41

PASTING WASTE CHARACTERISTICS
(mg/l)

PLANT EPA ID		A			D			E
Stream Identification POLLUTANTS		Clean Up Water From Pasting Machine			In-Line Sump Under Pasting Machine			
	Temperature (Deg C)	NA	NA	NA	29.0	NA	NA	NA
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	*	*	0.02	0.01	0.02	0.00
65	Phenol	NA	0.00	NA	NA	NA	NA	0.00
66	Bis(2-ethylhexyl)phthalate	*	0.00	0.00	*	*	0.11	*
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	3.67	0.00	0.00	0.31	0.13
115	Arsenic	0.00	0.00	0.00	0.00	0.00	0.00	NA
118	Cadmium	0.00	0.00	0.18	0.01	0.01	0.04	0.03
119	Chromium, Total	0.00	0.00	0.00	0.03	0.02	0.03	NA
	Chromium, Hexavalent	0.00	0.00	0.00	NA	NA	NA	0.00
120	Copper	0.12	0.08	0.58	0.03	0.03	0.19	NA
122	Lead	2700.	6000.	3360.	280.	208.	254.	13.4
123	Mercury	0.02	0.00	I	0.00	0.00	0.00	0.05
124	Nickel	0.00	0.00	0.00	0.03	0.02	0.02	NA
126	Silver	0.26	0.19	0.71	0.01	0.01	0.18	0.01
128	Zinc	0.04	0.16	0.51	0.78	0.54	0.41	3.88
	Iron	0.80	2.65	7.23	0.76	0.54	2.03	390.
	Phenols, Total	0.09	0.15	0.11	0.06	0.08	0.07	0.02
	Strontium	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	Oil & Grease	38.0	1620.	1200.	9.30	35.0	30.0	3.00
	Total Suspended Solids	10900.	12500.	42300.	6600.	20900.	11000.	184.
	pH, Minimum	7.2	9.8	11.4	6.1	NA	NA	NA
	pH, Maximum	7.9	9.8	11.4	6.1	NA	NA	NA

I-Interference
NA-Not Analyzed
*-Less than 0.01

Table V-42

PASTING WASTE LOADINGS
(mg/kg)

PLANT EPA ID	A			D			E
Stream Identification POLLUTANTS	Clean-Up Water From Pasting Machine			In-Line Sump Under Pasting Machine			
Flow (l/kg)	0.31	0.35	0.32	0.06	0.06	0.06	0.22
Temperature (Deg C)	NA	NA	NA	29.0	NA	NA	NA
11 1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23 Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44 Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55 Naphthalene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 Phenol	NA	0.00	NA	NA	NA	NA	0.00
66 Bis(2-ethylhexyl)phthalate	0.00	0.00	0.00	0.00	0.00	0.01	0.00
67 Butyl benzyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68 Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69 Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78 Anthracene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81 Phenanthrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84 Pyrene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114 Antimony	0.00	0.00	1.16	0.00	0.00	0.02	0.03
115 Arsenic	0.00	0.00	0.00	0.00	0.00	0.00	NA
118 Cadmium	0.00	0.00	0.06	0.00	0.00	0.002	0.01
119 Chromium, Total	0.00	0.00	0.00	0.002	0.001	0.002	NA
Chromium, Hexavalent	0.00	0.00	0.00	NA	NA	NA	0.00
120 Copper	0.04	0.03	0.18	0.001	0.002	0.01	NA
122 Lead	840.	2100.	1060.	16.3	13.2	16.2	2.92
123 Mercury	0.01	0.00	I	0.00	0.00	0.00	0.01
124 Nickel	0.00	0.00	0.00	0.002	0.001	0.002	NA
126 Silver	0.08	0.07	0.22	0.001	0.001	0.01	0.002
128 Zinc	0.01	0.06	0.16	0.05	0.03	0.03	0.85
Iron	0.25	0.93	2.30	0.04	0.03	0.13	85.0
Phenols, Total	0.03	0.05	0.04	0.004	0.01	0.004	0.004
Strontium	0.00	0.00	0.00	0.00	0.00	0.001	0.00
Oil & Grease	11.8	568.	378.	0.54	2.22	1.93	0.65
Total Suspended Solids	3390.	4370.	13400.	383.	1320.	704.	40.1
pH, Minimum	7.2	9.8	11.4	6.1	NA	NA	NA
pH, Maximum	7.9	9.8	11.4	6.1	NA	NA	NA

I-Interference
NA-Not Analyzed

Table V-43

CLOSED FORMATION POLLUTANT
CHARACTERISTICS OF BOTH
WET AND DAMP BATTERIES
Plant A

(mg/l)

	POLLUTANTS	WET BATTERIES			DAMP BATTERIES	
	Temperature (Deg C)	18.5	20.0	18.0	20.0	18.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	*	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	0.00	NA
66	Bis(2-ethylhexyl)phthalate	*	*	*	*	0.01
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00	0.00	0.05
118	Cadmium	0.00	0.01	0.01	0.01	0.01
119	Chromium, Total	0.03	0.07	0.05	0.06	0.17
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00
120	Copper	0.10	0.17	0.40	0.33	0.46
122	Lead	0.96	1.71	0.85	1.71	1.96
123	Mercury	0.00	0.02	0.00	0.00	0.00
124	Nickel	0.01	0.04	0.02	0.04	0.14
126	Silver	0.00	0.00	0.00	0.00	0.00
128	Zinc	0.06	0.08	0.18	0.10	0.17
	Iron	3.90	7.92	5.10	4.40	9.36
	Phenols, Total	0.02	0.01	0.08	0.02	0.02
	Strontium	0.00	0.00	0.00	0.00	0.00
	Oil & Grease	1.00	1.10	4.20	1.30	1.20
	Total Suspended Solids	6.00	8.00	1.00	8.00	13.0
	pH, Minimum	2.0	2.0	2.0	2.0	NA
	pH, Maximum	6.8	2.4	2.6	5.7	2.0

NA-Not Analyzed
*-Less than 0.01

Table V-44

CLOSED FORMATION WASTE LOADINGS OF BOTH
WET AND DAMP BATTERIES
PLANT A

(mg/kg)

	POLLUTANTS	WET BATTERIES			DAMP BATTERIES	
	Flow (l/kg)	0.52	0.45	0.38	1.68	0.91
	Temperature (Deg C)	18.5	10.0	18.0	20.0	18.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	0.00	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.00	0.00	0.01
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00	0.00	0.05
118	Cadmium	0.00	0.002	0.002	0.01	0.01
119	Chromium, Total	0.01	0.03	0.02	0.11	0.16
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00
120	Copper	0.05	0.08	0.15	0.55	0.42
122	Lead	0.50	0.78	0.32	2.87	1.79
123	Mercury	0.00	0.01	0.00	0.00	0.00
124	Nickel	0.004	0.02	0.01	0.07	0.13
126	Silver	0.00	0.00	0.00	0.00	0.00
128	Zinc	0.03	0.04	0.07	0.17	0.16
	Iron	2.03	3.60	1.93	7.39	8.54
	Phenols, Total	0.01	0.01	0.03	0.03	0.02
	Strontium	0.00	0.00	0.00	0.00	0.00
	Oil & Grease	0.52	0.50	1.59	2.18	1.10
	Total Suspended Solids	3.12	3.63	0.38	13.4	11.9
	pH, Minimum	2.0	2.0	2.0	2.0	NA
	pH, Maximum	6.8	2.4	2.6	5.7	2.0

NA-Not Analyzed

Table V-45

OPEN FORMATION DEHYDRATED BATTERY
WASTE CHARACTERISTICS
(mg/l)

	POLLUTANTS	Plant D DAYS 1	2
	Temperature (Deg C)	50.0	48.0
11	1,1,1-Trichloroethane	NA	0.00
23	Chlorofom	NA	0.00
44	Methylene chloride	NA	0.00
55	Naphthalene	0.00	0.00
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.08	0.05
67	Butyl benzyl phthalate	0.00	0.00
68	Di-n-butyl phthalate	*	*
69	Di-n-octyl phthalate	0.00	0.00
78	Anthracene	0.00	0.00
81	Phenanthrene	0.00	0.00
84	Pyrene	0.00	0.00
114	Antimony	0.00	0.00
115	Arsenic	0.00	0.00
118	Cadmium	0.00	0.01
119	Chromium, Total	0.05	0.05
	Chromium, Hexavalent	NA	NA
120	Copper	0.05	0.04
122	Lead	8.59	6.72
123	Mercury	0.00	0.00
124	Nickel	0.10	0.13
126	Silver	0.00	0.00
128	Zinc	0.35	0.33
	Iron	0.93	2.21
	Phenols, Total	0.02	0.01
	Strontium	0.00	0.00
	Oil & Grease	5.70	2.40
	Total Suspended Solids	9.00	0.00
	pH, Minimum	2.0	2.0
	pH, Maximum	4.1	5.4

NA-Not Analyzed
*-Less than 0.01

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Table V-46

OPEN FORMATION DEHYDRATED BATTERY
WASTE LOADINGS
(mg/kg)

	POLLUTANTS	PLANT D DAYS	
		1	2
	Flow (l/kg)	16.1	11.7
	Temperature (Deg C)	50.0	48.0
11	1,1,1-Trichloroethane	NA	0.00
23	Chloroform	NA	0.00
44	Methylene chloride	NA	0.00
55	Naphthalene	0.01	0.01
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	1.24	0.60
67	Butyl benzyl phthalate	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00
78	Anthracene	0.01	0.01
81	Phenanthrene	0.01	0.01
84	Pyrene	0.00	0.00
114	Antimony	0.00	0.00
115	Arsenic	0.00	0.00
118	Cadmium	0.00	0.11
119	Chromium, Total	0.76	0.56
	Chromium, Hexavalent	NA	NA
120	Copper	0.74	0.42
122	Lead	138.	78.9
123	Mercury	0.00	0.00
124	Nickel	1.55	1.53
126	Silver	0.00	0.00
128	Zinc	5.64	3.88
	Iron	15.0	26.0
	Phenols, Total	0.26	0.06
	Strontium	0.00	0.00
	Oil & Grease	91.8	28.1
	Total Suspended Solids	145.	0.00
	pH, Minimum	2.0	2.0
	pH, Maximum	4.1	5.4

NA-Not Analyzed

Table V-47

BATTERY WASH WASTEWATER CHARACTERISTICS
(mg/l)

		PLANT A				PLANT D	
	Temperature (Deg C)	18.0	18.0	18.0	28.0	28.0	28.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	*	*
23	Chloroform	0.00	0.00	0.00	0.00	*	*
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.01	0.03	0.04	0.00	*	0.00
65	Phenol	NA	0.00	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	*	0.02	0.01	0.05	0.04
67	Butyl benzyl phthalate	*	0.00	*	*	0.00	*
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	*	*	*
78	Anthracene	0.00	*	*	0.00	0.00	0.00
81	Phenanthrene	0.00	*	*	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.19	0.18
115	Arsenic	0.00	0.00	0.00	0.00	0.00	0.13
118	Cadmium	0.00	0.00	0.00	0.00	0.00	0.00
119	Chromium, Total	0.07	0.00	0.02	1.16	1.45	3.67
	Chromium, Hexavalent	0.00	0.00	0.00	NA	NA	NA
120	Copper	0.57	0.28	0.33	0.29	1.47	2.79
122	Lead	6.39	1.20	1.37	8.42	9.69	18.9
123	Mercury	0.00	0.01	0.07	0.00	0.00	0.00
124	Nickel	0.06	0.00	0.01	0.63	0.91	2.80
126	Silver	0.00	0.00	0.00	0.00	0.00	0.00
128	Zinc	0.24	0.13	0.16	0.81	1.77	7.60
	Iron	6.93	3.90	5.00	26.8	40.0	83.0
	Phenols, Total	0.02	0.01	0.02	0.02	0.02	0.02
	Strontium	0.04	0.00	0.00	0.00	0.00	0.00
	Oil & Grease	18.0	23.0	17.0	14.0	10.4	15.0
	Total Suspended Solids	120.	19.0	29.0	160.	70.0	93.0
	pH, Minimum	2.0	2.0	2.0	2.0	2.0	2.0
	pH, Maximum	7.7	6.8	5.7	12.0	12.0	12.0

NA-Not Analyzed
*-Less than 0.01

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Table V-48

BATTERY WASH WASTEWATER LOADINGS
(mg/kg)

	POLLUTANTS	PLANT A			PLANT D		
	Flow (l/kg)	0.65	0.64	0.28	0.73	0.60	0.50
	Temperature (Deg C)	18.0	18.0	18.0	28.0	28.0	28.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.01	0.02	0.01	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.01	0.01	0.03	0.02
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.11	0.09
115	Arsenic	0.00	0.00	0.00	0.00	0.00	0.08
118	Cadmium	0.001	0.00	0.001	0.00	0.004	0.00
119	Chromium, Total	0.05	0.00	0.01	0.85	0.87	1.84
	Chromium, Hexavalent	0.00	0.00	0.00	NA	NA	NA
120	Copper	0.37	0.18	0.09	0.21	0.88	1.40
122	Lead	4.16	0.77	0.38	6.15	5.81	9.45
123	Mercury	0.00	0.01	0.02	0.00	0.00	0.00
124	Nickel	0.04	0.00	0.002	0.05	0.55	1.40
126	Silver	0.00	0.00	0.00	0.00	0.00	0.003
128	Zinc	0.16	0.08	0.05	0.59	1.06	3.80
	Iron	4.51	2.49	1.40	19.6	24.0	41.5
	Phenols, Total	0.01	0.01	0.01	0.01	0.01	0.01
	Strontium	0.03	0.00	0.00	0.00	0.00	0.00
	Oil & Grease	11.7	14.7	4.77	10.2	6.24	7.50
	Total Suspended Solids	78.1	12.1	8.13	117.	42.0	46.5
	pH, Minimum	2.0	2.0	2.0	2.0	2.0	2.0
	pH, Maximum	7.7	6.8	5.7	12.0	12.0	12.0

NA-Not Analyzed

Table V-49

BATTERY REPAIR AND FLOOR WASH WASTE CHARACTERISTICS
(mg/l)

POLLUTANTS		FLOOR WASH PLANT A			BATTERY REPAIR PLANT A			PLANT D	
DAYS		1	2	3	1	2	3	1	2
	Temperature (Deg C)	NA	22.0	NA	NA	NA	NA	32.0	31.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	*	*	NA	*	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	NA	0.00	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	*	*	NA	0.01	0.01	0.01	0.01
67	Butyl benzyl phthalate	*	0.00	0.00	NA	*	*	0.00	*
68	Di-n-butyl phthalate	0.00	0.00	0.00	NA	0.01	0.01	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	NA	*	*	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	NA	*	*	0.00	0.00
84	Pyrene	0.00	0.00	0.00	NA	*	0.00	0.00	0.00
114	Antimony	0.94	0.00	0.00	0.64	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00	0.11	0.00	0.00	0.15	0.00
118	Cadmium	0.04	0.04	0.01	0.22	0.34	0.01	0.01	0.00
119	Chromium, Total	0.03	0.02	0.02	0.25	0.10	0.01	0.25	0.12
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
120	Copper	0.29	0.21	0.32	5.46	9.83	0.28	1.22	0.25
122	Lead	251.	107.	51.0	65.0	0.54	0.27	1.02	0.83
123	Mercury	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00
124	Nickel	0.03	0.02	0.00	0.43	0.52	0.01	0.13	0.17
126	Silver	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
128	Zinc	0.94	0.71	0.47	9.87	7.51	4.21	1.41	0.50
	Iron	9.76	6.82	6.45	460.	370.	8.05	5.94	2.31
	Phenols, Total	0.15	0.09	0.16	0.04	0.17	0.13	0.01	0.09
	Strontium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil & Grease	NA	25.0	28.0	62.0	46.0	54.0	6.00	9.30
	Total Suspended Solids	NA	1120.	952.	624.	362.	572.	1.30	12.0
	pH, Minimum	NA	NA	NA	2.3	NA	NA	2.9	3.4
	pH, Maximum	NA	10.2	10.2	2.3	2.0	NA	3.9	5.6

NA-Not Analyzed
*-Less than 0.01

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Table V-50

BATTERY REPAIR AND FLOOR WASH WASTE LOADINGS
(mg/kg)

POLLUTANTS		FLOOR WASH PLANT A			BATTERY REPAIR PLANT A			PLANT D	
		1	2	3	1	2	3	1	2
	Flow (l/kg)	0.03	0.02	0.03	0.003	0.004	0.004	0.17	0.32
	Temperature (Deg C)	NA	22.0	NA	NA	NA	NA	32.0	31.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	NA	0.00	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.00	NA	0.00	0.00	0.002	0.004
67	Butyl benzyl phthalate	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
78	Anthracene	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
84	Pyrene	0.00	0.00	0.00	NA	0.00	0.00	0.00	0.00
114	Antimony	0.03	0.00	0.00	0.002	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
118	Cadmium	0.001	0.001	0.00	0.001	0.001	0.00	0.002	0.00
119	Chromium, Total	0.001	0.00	0.00	0.001	0.00	0.00	0.04	0.04
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA
120	Copper	0.01	0.004	0.01	0.02	0.04	0.001	0.21	0.08
122	Lead	6.62	2.16	1.32	0.22	0.002	0.001	0.17	0.27
123	Mercury	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
124	Nickel	0.001	0.00	0.00	0.001	0.002	0.00	0.02	0.06
126	Silver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
128	Zinc	0.03	0.01	0.01	0.03	0.03	0.02	0.24	0.16
	Iron	0.26	0.14	0.17	1.55	1.44	0.03	1.01	0.74
	Phenols, Total	0.004	0.002	0.004	0.00	0.001	0.00	0.002	0.03
	Strontium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oil & Grease	NA	0.51	0.72	0.21	0.18	0.20	1.02	2.99
	Total Suspended Solids	NA	22.5	24.6	2.10	1.41	2.16	0.22	3.85
	pH, Minimum	NA	NA	NA	2.3	NA	NA	2.9	3.4
	pH, Maximum	NA	10.2	10.2	2.3	2.0	NA	3.9	5.6

NA-Not Analyzed

Table V-51

EFFLUENT FROM SAMPLED PLANTS
(mg/l)

	POLLUTANTS	Plant B			Plant C		
	DAYS	1	2	3	1	2	3
	Flow (l/kg)	5.60	4.08	3.40	6.58	6.48	6.87
	Temperature (Deg C)	17.0	17.0	17.0	7.60	7.80	8.50
11	1,1,1-Trichloroethane	*	*	*	*	*	0.27
23	Chloroform	0.03	0.00	0.00	0.00	0.00	*
44	Methylene chloride	*	0.00	0.00	0.00	*	0.00
55	Naphthalene	0.00	0.00	0.00	0.00	0.00	*
65	Phenol	*	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.02	*	*	*	*	*
67	Butyl benzyl phthalate	0.00	*	0.00	0.00	*	0.00
68	Di-n-butyl phthalate	*	0.00	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	0.00	*	0.00	0.00	0.00
78	Anthracene	*	0.00	0.00	0.00	0.00	0.00
81	Phenanthrene	*	0.00	0.00	0.00	0.00	0.00
84	Pyrene	*	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.00	0.00	0.00	0.00
119	Chromium, Total	0.00	0.01	0.01	0.00	0.01	0.01
	Chromium, Hexavalent	0.00	NA	NA	NA	NA	NA
120	Copper	0.00	0.04	0.03	0.02	0.01	0.02
122	Lead	1.35	4.05	3.58	0.11	0.13	0.11
123	Mercury	NA	0.00	0.00	0.00	0.00	0.00
124	Nickel	0.00	0.00	0.01	0.01	0.01	0.01
126	Silver	0.00	0.00	0.00	0.00	0.00	0.00
128	Zinc	0.10	0.10	0.08	0.00	0.00	0.04
	Iron	0.00	0.71	0.59	0.76	0.92	0.95
	Phenols, Total	0.00	0.00	0.00	0.00	0.00	0.00
	Strontium	NA	0.02	0.01	0.03	0.03	0.00
	Oil & Grease	10.0	9.90	5.00	1.40	2.70	2.20
	Total Suspended Solids	90.6	76.0	39.8	13.0	11.0	11.0
	pH, Minimum	6.5	7.2	6.6	9.0	8.7	8.6
	pH, Maximum	8.5	8.8	7.9	9.3	9.1	9.1

NA-Not Analyzed
*-Less than 0.01

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TABLE V- 51(CON'T)

EFFLUENT FROM SAMPLED PLANTS
(mg/l)

	COMPONENTS	Plant D		
	DAYS	1	2	3
	Flow (l/kg)	1.89	1.84	1.21
	Temperature (Deg C)	32.0	31.0	NA
11	1,1,1-Trichloroethane	*	*	*
23	Chloroform	*	*	*
44	Methylene chloride	*	*	*
55	Naphthalene	0.00	0.00	0.00
65	Phenol	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	0.02	0.00
67	Butyl benzyl phthalate	*	0.00	0.12
68	Di-n-butyl phthalate	*	0.00	*
69	Di-n-octyl phthalate	0.00	0.00	0.00
78	Anthracene	*	*	*
81	Phenenthrene	*	*	*
84	Pyrene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.00
119	Chromium, Total	0.01	0.01	0.06
	Chromium, Hexavalent	NA	NA	NA
120	Copper	0.06	0.05	0.09
122	Lead	6.06	3.88	13.3
123	Mercury	0.00	0.00	0.00
124	Nickel	0.11	0.07	0.05
126	Silver	0.00	0.00	0.00
128	Zinc	0.17	0.00	0.11
	Iron	0.42	0.28	3.38
	Phenols, Total	0.00	0.00	0.00
	Strontium	0.00	0.00	0.00
	Oil & Grease	2.30	1.70	3.70
	Total Suspended Solids	3.50	11.0	66.0
	pH, Minimum	6.0	7.7	7.0
	pH, Maximum	10.4	9.2	9.0

NA-Not Analyzed
*-Less than 0.01

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Table V-52

LECLANCHE SUBCATEGORY ELEMENTS (REPORTED MANUFACTURE)

Anodes

| Cathodes (and Electrolyte Form) | Zinc Sheet Metal | | | Zinc Powder |
	Cooked Paste Separator	Uncooked Paste Separator	Paper Separator	Plastic Separator
MnO_2 Cathode (and Electrolyte with Mercury)	-----	-----	X	-----
MnO_2 Cathodes (and Electrolyte without Mercury)	X	X	X	-----
MnO_2 Cathode (and Gelled Electrolyte with Mercury)	-----	-----	X	X
Carbon Cathode	-----	-----	X	-----
Silver Cathode	-----	X	-----	-----
Pasted MnO_2 Cathode	-----	-----	-----	X

Ancillary Operations

Equipment Cleanup	X	

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TABLE V-53
NORMALIZED DISCHARGE FLOWS
LECLANCHE SUBCATEGORY ELEMENTS

Elements	Mean Discharge (l/kg)	Median Discharge (l/kg)	Production Weighted Mean Raw Waste (l/kg)	Total Raw Waste Volume (l/yr)	Production Normalizing Parameter
Ancillary Operations					
Separator Cooked Paste	0.04	0.04	0.137	3.2×10^6	Weight of Cells Produced
Separator Pasted Paper with Mercury	0.14	0.14	0.14	1.5×10^4	Weight of Dry Paste Material
Equipment and Area Cleanup	0.38	0	0.103	9.65×10^6	Weight of Cells Produced

Table V-54

LECLANCHE SUBCATEGORY EFFLUENT QUALITY
(FROM DCP'S)

PARAMETER	Plant F	Plant E
Flow, l/kg	6.37	6.37
Oil & Grease, mg/l	24.6	-
Lead, mg/l	0.03	-
Mercury, mg/l	1.42	3.15
Nickel, mg/l	0.007	-
Zinc, mg/l	-	658.0

Table V-55

POLLUTANT CONCENTRATIONS OF THE COOKED
PASTE SEPARATOR ELEMENT WASTE STREAMS

	POLLUTANTS	1	mg/1 Days 2	3
	Flow			
	Temperature (Deg C)	59.9	59.9	59.9
70	Diethyl phthalate	*	0.00	*
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.01	0.02	0.02
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.08	0.08	0.13
122	Lead	0.00	0.00	0.00
123	Mercury	0.13	0.16	0.15
124	Nickel	0.03	0.05	0.10
125	Selenium	0.00	0.00	0.00
128	Zinc	85.0	94.0	148.
	Manganese	2.97	5.48	14.2
	Phenols, Total	0.01	0.01	0.01
	Oil & Grease	13.0	39.0	11.0
	Total Suspended Solids	119.	41.0	62.0
	pH, Minimum	5.1	5.1	5.9
	pH, Maximum	6.8	6.8	6.3

*--Less than 0.01

Table V-56

POLLUTANT MASS LOADINGS OF THE COOKED PASTE SEPARATOR ELEMENT WASTE STREAMS

	POLLUTANTS	1	mg/kg Days 2	3
	Flow (1/kg)	0.05	0.05	0.03
	Temperature (Deg C)	59.9	59.9	59.9
70	Diethyl phthalate	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.001	0.001	0.001
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.004	0.004	0.003
122	Lead	0.00	0.00	0.00
123	Mercury	0.01	0.01	0.002
124	Nickel	0.002	0.002	0.002
125	Selenium	0.00	0.00	0.00
128	Zinc	4.01	4.23	3.75
	Manganese	0.14	0.25	0.36
	Phenols, Total	0.001	0.00	0.00
	Oil & Grease	0.61	1.75	0.28
	Total Suspended Solids	5.62	1.84	1.57
	pH, Minimum	5.1	5.1	5.9
	pH, Maximum	6.8	6.8	6.3

Table V-57

POLLUTANT CONCENTRATIONS OF THE PAPER
SEPARATOR (WITH MERCURY) ELEMENTS
WASTE STREAMS

	POLLUTANTS	mg/l Days		
		1	2	3
	Temperature (Deg C)	31.0	31.1	30.0
70	Diethyl phthalate	*	*	*
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.47	0.02	0.02
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.11	0.08	0.09
122	Lead	0.07	0.00	0.00
123	Mercury	0.40	0.16	0.14
124	Nickel	0.14	0.02	0.03
125	Selenium	0.00	0.00	0.00
128	Zinc	1.16	0.41	0.23
	Manganese	1.15	1.25	0.43
	Phenols, Total	0.01	0.09	0.05
	Oil & Grease	16.0	7.00	83.0
	Total Suspended Solids	140.	7.00	96.0
	pH, Minimum	8.3	7.5	8.5
	pH, Maximum	8.3	8.5	8.6

Table V-58

POLLUTANT MASS LOADINGS OF THE PAPER
SEPARATOR (WITH MERCURY) ELEMENT
WASTE STREAMS

			mg/kg Days	
	POLLUTANTS	1	2	3
	Flow (l/kg)	0.11	0.17	0.15
	Temperature (Deg C)	31.0	31.1	30.0
70	Diethyl phthalate	*	*	*
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.05	0.003	0.004
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.01	0.01	0.01
122	Lead	0.01	0.00	0.00
123	Mercury	0.04	0.03	0.02
124	Nickel	0.02	0.003	0.004
125	Selenium	0.00	0.00	0.00
128	Zinc	0.13	0.07	0.04
	Manganese	0.13	0.22	0.07
	Phenols, Total	0.001	0.02	0.01
	Oil & Grease	1.74	1.22	12.6
	Total Suspended Solids	15.2	1.22	14.6
	pH, Minimum	8.3	7.5	8.5
	pH, Maximum	8.3	8.5	8.6

*-Less than 0.01

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Table V-59

FLOW RATES (1/kg) OF ANCILLARY OPERATION WASTE STREAMS

Plant Ref. No.	SAMPLING DATA MEAN VALUE, 1/kg	SURVEY DATA, 1/kg
1		0.05
2		0
3		0
4		0
5(B)	0.01	0.04
6		0
7		0
8		0
9		0
10		0
11		0
12(C)	0.01	
13(D)		6.37
14		0
15		0
16(E)		0.44
17		0.44
18		0
19		0

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TABLE V-60

POLLUTANT CONCENTRATIONS OF THE
EQUIPMENT AND AREA CLEANUP ELEMENT
WASTE STREAMS

POLLUTANTS		Plant B			Plant C			Plant E	Plant B	Plant D
	DAYS	1	2	3	1	2	3			
	Temperature (Deg C)	59.9	43.3	60.0	31.0	30.5	30.1			
70	Diethyl phthalate	*	*	*	*	*	*			
114	Antimony	0.00	0.00	0.00	0.00	0.00	0.00			
115	Arsenic	0.07	0.09	0.64	0.00	0.00	0.00			
118	Cadmium	0.04	0.02	0.09	0.05	0.04	0.19			
119	Chromium, Total	0.25	0.13	2.88	0.01	0.02	0.28			
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00	0.00			
120	Copper	0.22	0.16	3.22	0.09	0.10	0.11			
122	Lead	0.07	0.00	0.94	0.00	0.00	0.00			0.03
123	Mercury	I	I	I	0.02	0.03	0.03	117.	0.03	1.42
124	Nickel	0.78	0.22	10.1	0.57	0.33	0.37			0.01
125	Selenium	0.070	0.090	0.600	0.00	0.00	0.00			
128	Zinc	220.	325.	680.	98.0	42.4	33.8	1640.	410.	
	Manganese	140.	3.82	383.	33.9	21.8	13.3			
	Phenols, Total	0.06	I	I	0.06	0.25	0.04			
	Oil & Grease	33.0	482.	36.0	9.80	439.	96.1			24.6
	Total Suspended Solids	2610.	4220.	14200.	357.	395.	471.			
	pH, Minimum	7.5	7.5	8.5	6.2	6.1	6.1			
	pH, Maximum	10.4	10.4	9.7	8.6	9.0	8.7			

I-Interference

* Less than 0.01

Table V-61

POLLUTANT MASS LOADINGS OF THE
EQUIPMENT AND AREA CLEANUP ELEMENT
WASTE STREAMS

	POLLUTANTS	Plant B			Plant C			Plant E	Plant B	Plant D
	DAYS	1	2	3	1	2	3			
	Flow (l/kg)	0.01	0.01	0.01	0.01	0.01	0.01	0.44	0.04	6.37
	Temperature (Deg C)	59.0	43.3	60.0	31.0	30.5	30.1			
70	Diethyl phthalate	0.00	0.00	0.00	0.00	0.00	0.00			
114	Antimony	0.00	0.00	0.00	0.00	0.00	0.00			
115	Arsenic	0.001	0.001	0.01	0.00	0.00	0.00			
118	Cadmium	0.00	0.00	0.001	0.001	0.00	0.002			
119	Chromium, Total	0.002	0.001	0.03	0.00	0.00	0.003			
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0.00	0.00			
120	Copper	0.002	0.002	0.04	0.001	0.001	0.001			
122	Lead	0.001	0.00	0.01	0.00	0.00	0.00			6.19
123	Mercury	I	I	I	0.00	0.00	0.00	51.5	0.001	9.05
124	Nickel	0.01	0.002	0.11	0.01	0.003	0.004			0.04
125	Selenium	0.001	0.001	0.007	0.00	0.00	0.00			
128	Zinc	1.84	3.55	7.66	0.98	0.43	0.34	722.	16.4	
	Manganese	1.17	0.04	4.32	0.34	0.22	0.13			
	Phenols, Total	0.00	I	I	0.001	0.003	0.00			
	Oil & Grease	0.28	5.27	0.41	0.10	4.46	0.96			157.
	Total Suspended Solids	21.8	46.1	160.	3.58	4.02	4.72			
	pH, Minimum	7.5	7.5	8.5	6.2	6.1	6.1			
	pH, Maximum	10.4	10.4	9.7	8.6	9.0	8.7			

I-Interference

Table V-62

STATISTICAL ANALYSIS (mg/l) OF THE
EQUIPMENT AND AREA CLEANUP ELEMENT WASTE
STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median	# Val	# Zeros	# Pts
	Temperature (Deg C)	30.1	60.0	45.1	37.1	6	0	6
70	Diethyl phthalate	*	*	*	*	0	6	6
114	Antimony	0.00	0.00	0.00	0.00	0	6	6
115	Arsenic	0.00	0.64	0.13	0.04	3	3	6
118	Cadmium	0.02	0.19	0.07	0.05	6	0	6
119	Chromium, Total	0.01	2.88	0.60	0.19	6	0	6
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	6	6
120	Copper	0.09	3.22	0.65	0.13	6	0	6
122	Lead	0.00	0.94	0.15	0.00	3	4	7
123	Mercury	0.02	117.	19.8	0.03	6	0	6
124	Nickel	0.01	10.1	1.80	0.37	7	0	7
125	Selenium	0.0	0.60	0.13	0.04	3	3	6
128	Zinc	33.8	1640.	431.	273.	8	0	8
	Manganese	3.82	383.	99.3	27.9	6	0	6
	Phenols, Total	0.04	0.25	0.10	0.06	4	0	4
	Oil & Grease	9.80	482.	160.	36.0	7	0	7
	Total Suspended Solids	357.	14200.	3710.	1540.	6	0	6
	pH, Minimum	6.1	8.5	6.98	6.85	6	0	6
	pH, Maximum	8.6	10.4	9.47	9.35	6	0	6

* Less than 0.01

Number of values may include concentrations less than
0.005 shown as 0.00 on table.

STATISTICAL ANALYSIS (mg/kg) OF THE
EQUIPMENT AND AREA CLEANUP ELEMENT
WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median
	Flow	0.01	6.37	0.77	0.01
	Temperature (Deg C)	30.1	60.0	45.1	37.1
70	Diethyl phthalate	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.01	0.001	0.00
118	Cadmium	0.00	0.002	0.001	0.00
119	Chromium, Total	0.00	0.03	0.01	0.002
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.001	0.04	0.01	0.001
122	Lead	0.00	0.19	0.03	0.01
123	Mercury	0.00	51.5	10.1	0.001
124	Nickel	0.002	0.11	0.03	0.01
125	Selenium	0.00	0.007	0.001	0.00
128	Zinc	0.34	722.	94.3	2.7
	Manganese	0.04	4.32	1.04	0.28
	Phenols, Total	0.00	0.003	0.001	0.001
	Oil & Grease	0.10	157.	24.0	0.96
	Total Suspended Solids	3.58	160.	40.1	13.3
	pH, Minimum	6.1	8.5	6.98	6.85
	pH, Maximum	8.6	10.4	9.47	9.35

Table V-64

STATISTICAL ANALYSIS OF THE LECLANCHE SUBCATAGORY
RAW WASTE CONCENTRATIONS

	POLLUTANTS	MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZERO	# PTS.
	FLOW (1/day)	636.	5880.	2640.	1920.	6	0	6
	Temperature (Deg C)	30.1	59.9	55.3	43.8	6	0	6
70	Diethyl phthalate	*	*	*	*	0	6	6
114	Antimony	0.00	0.00	0.00	0.00	0	6	6
115	Arsenic	0.00	0.20	0.04	0.01	3	3	6
118	Cadium	0.02	0.17	0.06	0.04	6	0	6
119	Chromium,Total	0.01	0.89	0.21	0.03	6	0	6
	Chromium,Hexavalent	0.00	0.00	0.00	0.00	0	6	6
120	Copper	0.10	1.08	0.26	0.10	6	0	6
122	Lead	0.00	0.29	0.05	0.00	3	3	6
123	Mercury	0.04	0.13	0.08	0.07	6	0	6
124	Nickel	0.09	3.18	0.76	0.32	6	0	6
125	Selenium	0.00	0.185	0.035	0.01	3	3	6
128	Zinc	30.6	312.	119.	98.2	6	0	6
	Manganese	5.16	128.	36.6	21.6	6	0	6
	Phenols,Total	0.01	0.24	0.06	0.03	6	0	6
	Oil & Grease	10.2	392.	110.	56.8	6	0	6
	Total Suspended Solids	342.	4420.	1150.	464.	6	0	6
	pH, Minimum	5.1	6.2	5.7	6.0	6	0	6
	pH, Maximum	8.6	10.4	9.5	9.4	6	0	6

Number of values may include concentrations less than 0.005
shown as 0.00 on table.

* Less than 0.01

TABLE V-65
NORMALIZED DISCHARGE FLOWS
LITHIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (1/kg)	Median Discharge (1/kg)	Production Weighted Mean Raw Waste (1/kg)	Total Raw Waste Volume (1/yr)	Production Normalizing Parameter
Cathodes					
Sulfur Dioxide		0 - +	2.83	1.1×10^4	Weight of Sulfur Dioxide
Thionyl Chloride	108.	108.	108.	3.1×10^5	Weight of Thionyl Chloride
Iron Disulfide	7.54	7.54	7.54	1.7×10^5	Weight of Iron Disulfide
Ancillary Operations					
Heat Paper Production	+ +	+ +	+ +	+ +	Weight of Reactants
Lithium Scrap Disposal	+	+	+	+	Weight of Cells Produced
Leak Test	+ +	+ +	+ +	+ +	Weight of Cells Produced

+   Cannot be determined from presently available data.

+ + See calcium anode discussion

TABLE V-66
NORMALIZED DISCHARGE FLOWS
MAGNESIUM SUBCATEGORY ELEMENTS

Elements	Mean Discharge (1/kg)	Median Discharge (1/kg)	Production Weighted Mean Raw Waste (1/kg)	Total Raw Waste Volume (1/yr)	Production Normalizing Parameter
Cathodes					
Silver Chloride Cathode-Surface Reduced	3310.	3310.	3310.	8.8×10^5	Weight of Depolarizer Material
Silver Chloride Cathode-Electro-lytic	1637.	1637.	1637.	2.3×10^5	Weight of Depolarizer Material
Vanadium Pentoxide Cathode	1652.	1652.	1652.	3.6×10^6	Weight of Depolarizer Material
Ancillary Operations					
Cell Test	52.6	52.6	5.26	9.1×10^4	Weight of Cells Produced
Separator Processing	+	+	+	3.6×10^4	Weight of Cells Produced
Floor Wash	2.9	2.9	2.9	1.3×10^4	Weight of Cells Produced
Heat Paper Manufacture	++	++	792.	6.8×10^6	Weight of Reactive Materials

+ Cannot be calculated from present information.

++See Calcium Anode

Table V-67

MAGNESIUM SUBCATEGORY PROCESS
WASTEWATER FLOW RATES FROM
INDIVIDUAL FACILITIES

Plant ID #	Flow Rate (1/day)
A	4.18×10^4
B	0
C	872
D	0
E	2990
F	+
G	0
H	0

+ Not Available

Table V-68

ZINC SUBCATEGORY PROCESS ELEMENTS
(REPORTED MANUFACTURE)

ZINC ANODES

Cathodes	Zinc Powder				Zinc Oxide Powder		
	Cast or Fabricated	Wet Amalgamated	Gelled Amalgam	Dry Amalgamated	Pasted or Pressed on Grid	Pasted or Pressed-Reduced	Electrodeposited
Agglo (Porous Carbon)	X						
Manganese Dioxide-Carbon		X	X	X			
Mercuric Oxide (and Mercuric Oxide-Manganese Dioxide-Carbon)		X	X				
Mercuric Oxide-Cadmium Oxide		X					
Silver Powder							
Pressed Only					X		
Pressed and Electrolytically Oxidized						X	X
Silver Oxide							
Reduced-Sintered and Electrolytically Formed						X	X
Pressed		X					
Blended (MnO_2, Mg_2O)							
Blended (Incl. HgO)		X	X				

Table V-68 (con't)

ZINC SUBCATEGORY PROCESS ELEMENTS

ZINC ANODES

Cathodes	Zinc Powder				Zinc Oxide Powder		
	Cast or Fabricated	Wet Amalgamated	Gelled Amalgam	Dry Amalgamated	Pasted or Pressed on Grid	Pasted or Pressed-Reduced	Electrodeposited
Silver Peroxide			X				X
Nickel-Sintered, Impregnated and Formed						X	
Ancillary Operations							
Cell Wash		X					
Electrolyte Preparation		X					
Silver Etch		X					
Mandatory Employee Wash		X					
Reject Cell Handling		X					
Floor Wash		X					
Equipment Wash		X					
Silver Powder Production		X					
Silver Peroixde Production		X					

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Table V-69

OBSERVED FLOW RATES FOR
EACH PLANT IN ZINC SUBCATEGORY

	Observed Flow Rate (1/day)	
Plant Number	DCP Data	Mean Visit Data
A	+	3,722.9
B	25,432.2	101,892.2
C	3,494.2	
D	+	
E	16,118.2	27,271.2
F	4,008.0	23,305.5
G	77,516.8	
H	144,000	54,186.1
I	0	
J	16.0	
K	27,500	11,506.4
L	10,900.8	
M	0	
N	22,619.2	9.687.1
O	4,542.4	
P	21,206.4	13,471.6

+ Data not Available.

TABLE V-70
NORMALIZED DISCHARGE FLOWS
ZINC SUBCATEGORY ELEMENTS

Elements	Mean Discharge (1/kg)	Median Discharge (1/kg)	Production Weighted Mean. Raw Waste (1/kg)	Total Raw Waste Volume (1/yr)	Production Normalizing Parameter
Anodes					
Zinc Powder-Wet Amalgamated	3.8	2.2	3.86	5.6×10^6	Weight of Zinc
Zinc Powder-Gelled Amalgam	0.68	0.68	0.44	4.8×10^5	Weight of Zinc
Zinc Oxide Powder-Pasted or Pressed, Reduced	143.	117.	150.	4.9×10^6	Weight of Zinc
Zinc Electrodeposited	3190.	3190.	2792.	1.5×10^7	Weight of Deposited Zinc
Silver Powder Pressed and Electrolytically Oxidized	196.	196.	141.	7.5×10^6	Weight of Applied Silver
Silver Oxide (Ag_2O) Powder-Thermally Reduced or Sintered, Electrolytically Formed	131.	131.	198.	6.6×10^4	Weight of Applied Silver
Silver Peroxide Powder	31.4	12.8	8.78	2.3×10^5	Weight of Applied Silver
Nickel Impregnated and Formed	1640.	1720.	1640.	–	Weight of Deposited Nickel
Ancillary Operations					
Cell Wash	6.35	0.34	1.47	1.9×10^7	Weight of Finished Cells
Electrolyte Preparation	0.12	0.	0.071	1.3×10^6	Weight of Finished Cells
Silver Etch	49.1	49.1	49.1	2.8×10^3	Weight of Silver Processed
Mandatory Employee Wash	0.27	0.27	0.27	2.6×10^6	Weight of Finished Cells
Reject Cell Handling	0.01	0.002	0.002	2.2×10^4	Weight of Finished Cells
Floor Wash	0.1	0.1	0.026	2.4×10^5	Weight of Finished Cells
Equipment Wash	7.1	7.1	5.88	1.2×10^6	Weight of Finished Cells
Silver Peroxide Production	52.2	52.2	15.9	3.7×10^5	Weight of Silver in Peroxide Produced
Silver Powder Production	21.2	21.2	21.2	8.0×10^5	Weight of Silver Powder Produced

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Table V-71

TREATMENT PRACTICES AND EFFLUENT QUALITY AT ZINC SUBCATEGORY PLANTS
EFFLUENT ANALYSIS

EPA ID	TREATMENT	Cd	Cr	Cu	CN	Pb	Hg	Ni	Ag	Zn	NH$_3$	Fe	Mn	TSS	pH
A	pH Adj-Settle-Filter			0.8			.04			1.3					
B	Settle	0.20		1.0	0.005		.01			2.0				30.	6-9.5
C	Settle	0.10		8.	0.01	.8		.16	.02	274.		2.52	.84		
	Filter-Carbon Adsorption	ND		10.		10.	.00017	10.	10.	.37		10.	.50	10.	
D	Skim-Filter-Carbon Adsorption						.0086			2.1			4.1		11.7
E	pH Adjust-Chem Precipitation Settle-Filter						.20								
F	pH Adjust-Chem Precipitation-Settle		.10				.01			.70					
G			.21				.13			.74		10	2.9	92	
H	Filter-Carbon Adsorption						0.0005	ND		.03					
I	Amalgamation-Settle						0.076			3.99					
J	Amalgamation-Settle		.005		.047	.018	0.032	.005	1.24	.291	8.		.281	200.	11.2
K	Settle				.0403	.006	.19		.143	.194	15.	.235			8.2

Table V-72

POLLUTANT CONCENTRATIONS IN THE ZINC POWDER
WET AMALGAMATED ANODE ELEMENT WASTE STREAMS

mg/l

POLLUTANTS/DAYS		Plant A 1	2	3	Plant B 1	2	3
	Temperature (Deg C)	14.0	21.0	18.0	28.0	28.0	28.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.03	NA	NA	NA
29	1,1-Dichloroethylene	0.00	0.00	0.00	NA	NA	NA
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	NA	NA	NA
38	Ethylbenzene	0.00	0.00	0.00	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	*	0.00	0.00	NA	NA	NA
64	Pentachlorophenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	0.04	*	0.07
70	Diethyl phthalate	0.00	0.00	0.00	NA	NA	NA
85	Tetrachloroethylene	0.00	0.00	0.00	NA	NA	NA
86	Toluene	0.00	0.00	0.00	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.08	0.14	0.08	0.00	0.00	0.00
118	Cadmium	0.00	0.01	0.00	0.00	0.00	0.00
119	Chromium, Total	0.14	0.21	0.03	0.00	0.01	0.02
	Chromium, Hexavalent	0.11	0.14	0.03	0.00	0.00	0.00
120	Copper	0.01	0.01	0.01	0.04	0.02	0.00
121	Cyanide, Total	0.00	0.03	0.00	0.00	0.00	0.00
	Cyanide, Amn. to Chlor.	I	I	I	0.00	0.00	0.00
122	Lead	0.00	0.00	0.00	0.00	0.00	0.00
123	Mercury	I	I	I	0.60	0.50	0.26
124	Nickel	0.00	0.00	0.00	0.00	0.00	0.00
125	Selenium	0.00	0.00	0.00	NA	NA	NA
126	Silver	0.00	0.00	0.00	0.02	0.01	0.02
128	Zinc	35.3	22.0	47.4	450.	1050.	206.
	Aluminum	0.00	0.00	0.00	NA	NA	NA
	Ammonia	NA	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA	NA
	Manganese	0.03	0.06	0.09	0.04	0.03	0.01
	Phenols, Total	0.08	0.06	0.11	0.00	0.00	0.00
	Oil & Grease	2.00	2.80	9.20	10.0	9.00	22.0
	Total Suspended Solids	0.00	32.0	25.0	5.00	5.00	5.00
	pH, Minimum	8.8	8.2	8.4	4.3	4.3	4.3
	pH, Maximum	8.8	8.5	8.8	6.5	6.5	6.5

I-Interference
NA-Not Analyzed
*-Less than 0.01

Table V-73

POLLUTANT MASS LOADINGS IN THE ZINC
POWDER-WET AMALGAMATED ANODE
ELEMENT WASTE STREAMS
(mg/kg)

	POLLUTANTS/DAYS	Plant A			Plant B		
		1	2	3	1	2	3
	Flow (1/kg)	5.17	6.82	6.82	2.38	1.88	2.16
	Temperature (Deg C)	14.0	21.0	18.0	28.0	28.0	28.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.21	NA	NA	NA
29	1,1-Dichloroethylene	0.00	0.00	0.00	NA	NA	NA
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	NA	NA	NA
38	Ethylbenzene	0.00	0.00	0.00	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	NA	NA	NA
64	Pentachlorophenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	0.10	0.00	0.15
70	Diethyl phthalate	0.00	0.00	0.00	NA	NA	NA
85	Tetrachloroethylene	0.00	0.00	0.00	NA	NA	NA
86	Toluene	0.00	0.00	0.00	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.41	0.96	0.55	0.00	0.00	0.00
118	Cadmium	0.01	0.04	0.0	0.0	0.0	0.0
119	Chromium, Total	0.72	1.43	0.23	0.01	0.01	0.04
	Chromium, Hexavalent	0.57	0.96	0.21	0.00	0.00	0.00
120	Copper	0.03	0.07	0.08	0.09	0.04	0.00
121	Cyanide, Total	0.00	0.18	0.00	0.00	0.00	0.00
	Cyanide, Amn. to Chlor.	I	I	I	0.00	0.00	0.00
122	Lead	0.00	0.00	0.00	0.00	0.00	0.00
123	Mercury	I	I	I	1.43	0.94	0.56
124	Nickel	0.00	0.00	0.00	0.00	0.00	0.00
125	Selenium	0.00	0.00	0.00	NA	NA	NA
126	Silver	0.00	0.00	0.00	0.05	0.03	0.04
128	Zinc	182.	150.	323.	1070.	1980.	445.
	Aluminum	0.00	0.00	0.00	NA	NA	NA
	Ammonia	NA	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA	NA
	Manganese	0.16	0.38	0.61	0.10	0.06	0.02
	Phenols, Total	0.46	0.38	0.75	0.00	0.00	0.00
	Oil & Grease	10.3	19.1	62.7	23.8	17.0	47.5
	Total Suspended Solids	0.00	218.	171.	11.9	9.4	10.8
	pH, Minimum	8.8	8.2	8.4	4.3	4.3	4.3
	pH, Maximum	8.8	8.5	8.8	6.5	6.5	6.5

I-Interference
NA-Not Analyzed

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Table V-74

STATISTICAL ANALYSIS (mg/l) OF THE ZINC POWDER-WET AMALGAMATED ANODE ELEMENT WASTE STREAMS

POLLUTANTS	Minimum	Maximum	Mean	# Median	# Val	# Zeros	Pts
Temperature (Deg C)	14.0	28.0	22.6	24.5	6	0	6
11 1,1,1-Trichloroethane	0.00	*	*	*	3	3	6
13 1,1-Dichloroethane	0.00	0.03	*	0.00	1	2	3
29 1,1-Dichloroethylene	0.00	*	*	0.00	1	2	3
30 1,2-Trans-dichloroethylene	0.00	*	*	0.00	1	2	3
38 Ethylbenzene	0.00	0.00	0.00	0.00	0	3	3
44 Methylene chloride	0.00	*	*	0.00	1	5	6
55 Naphthalene	*	*	*	*	3	0	3
64 Pentachlorophenol	NA	NA	NA	NA			
66 Bis(2-ethylhexyl) phthalate	0.01	0.07	0.04	0.04	3	0	3
70 Diethyl phthalate	0.00	*	*	0.00	1	2	3
85 Tetrachloroethylene	0.00	*	*	0.00	1	2	3
86 Toluene	0.00	0.00	0.00	0.00	0	3	3
87 Trichloroethylene	0.00	*	*	0.00	2	4	6
114 Antimony	0.00	0.00	0.00	0.00	0	6	6
115 Arsenic	0.00	0.14	0.05	0.04	3	3	6
118 Cadmium	0.00	0.01	0.00	0.00	2	4	6
119 Chromium, Total	0.00	0.21	0.07	0.03	6	0	6
Chromium, Hexavalent	0.00	0.14	0.05	0.02	3	3	6
120 Copper	0.00	0.04	0.01	0.01	5	1	6
121 Cyanide, Total	0.00	0.03	0.00	0.00	1	5	6
Cyanide, Am. to Chlor.	0.00	0.00	0.00	0.00	0	3	3
122 Lead	0.00	0.00	0.00	0.00	0	6	6
123 Mercury	0.26	0.60	0.45	0.50	3	0	3
124 Nickel	0.00	0.00	0.00	0.00	0	6	6
125 Selenium	0.00	0.00	0.00	0.00	0	3	3
126 Silver	0.00	0.02	0.01	0.01	3	3	6
128 Zinc	22.0	1050.	302.	127.	6	0	6
Aluminum	0.00	0.00	0.00	0.00	0	3	3
Ammonia	NA	NA	NA	NA			
Iron	NA	NA	NA	NA			
Manganese	0.01	0.09	0.04	0.04	6	0	6
Phenols, Total	0.00	0.11	0.04	0.03	3	3	6
Oil & Grease	2.00	22.0	9.20	9.10	6	0	6
Total Suspended Solids	0.00	32.0	12.0	5.00	5	1	6
pH, Minimum	4.3	8.8	6.4	6.3	6	0	6
pH, Maximum	6.5	8.8	7.6	7.5	6	0	6

NA-Not Analyzed
*-Less than 0.01

Table V-75

STATISTICAL ANALYSIS (mg/kg) OF THE ZINC
POWDER-WET AMALGAMATED ANODE ELEMENT
WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median
	Flow (1/kg)	1.88	6.82	4.21	3.77
	Temperature (Deg C)	14.0	28.0	22.6	24.5
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.21	0.07	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.03	0.01	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	0.01	0.15	0.09	0.10
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.96	0.32	0.21
118	Cadmium	0.00	0.04	0.01	0.00
119	Chromium, Total	0.01	1.43	0.41	0.14
	Chromium, Hexavalent	0.00	0.96	0.29	0.10
120	Copper	0.00	0.09	0.05	0.05
121	Cyanide, Total	0.00	0.18	0.03	0.00
	Cyanide, Amn. to Chlor.	0.00	0.00	0.00	0.00
122	Lead	0.00	0.00	0.00	0.00
123	Mercury	0.56	1.43	0.98	0.94
124	Nickel	0.00	0.00	0.00	0.00
125	Selenium	0.00	0.00	0.00	0.00
126	Silver	0.00	0.05	0.02	0.01
128	Zinc	150.	1980.	692.	384.
	Aluminum	0.00	0.00	0.00	0.00
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.02	0.61	0.22	0.13
	Phenols, Total	0.00	0.75	0.26	0.19
	Oil & Grease	10.3	62.7	30.1	21.4
	Total Suspended Solids	0.00	218.	70.1	11.3
	pH, Minimum	4.3	8.8	6.4	6.3
	pH, Maximum	6.5	8.8	7.6	7.5

NA-Not Analyzed

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TABLE V-76

POLLUTANT CONCETRATIONS IN THE ZINC POWDER-GELLED AMALGAM ANODE ELEMENT WASTE STREAMS
(mg/l)

POLLUTANTS/DAYS	Plant A			Plant B		
	1	2	3	1	2	3
Temperature (Deg C)	21.0	26.0	22.0	16.0	15.0	16.0
11 1,1,1-Trichloroethane	*	NA	0.03	*	0.00	0.00
13 1,1-Dichloroethane	NA	NA	NA	NA	NA	NA
29 1,1-Dichloroethylene	NA	NA	NA	NA	NA	NA
30 1,2-Trans-dichloroethylene	NA	NA	NA	NA	NA	NA
38 Ethylbenzene	NA	NA	NA	NA	NA	NA
44 Methylene chloride	0.00	NA	0.00	0.02	0.00	0.00
55 Naphthalene	NA	NA	NA	NA	NA	NA
64 Pentachlorophenol	0.00	0.00	0.00	0.04	0.00	0.00
66 Bis(2-ethylhexyl) phthalate	0.01	0.01	0.04	0.01	0.00	*
70 Diethyl phthalate	NA	NA	NA	NA	NA	NA
85 Tetrachloroethylene	NA	NA	NA	NA	NA	NA
86 Toluene	NA	NA	NA	NA	NA	NA
87 Trichloroethylene	*	NA	*	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00	0.00	0.00
115 Arsenic	1.06	1.05	0.81	0.00	0.08	0.07
118 Cadmium	0.08	0.12	0.07	0.06	0.01	0.01
119 Chromium, Total	0.00	0.04	0.07	0.02	0.01	0.01
Chromium, Hexavalent	0.00	0.00	I	0.00	0.00	I
120 Copper	0.67	0.54	0.62	0.10	0.08	0.05
121 Cyanide, Total	NA	NA	NA	NA	0.01	0.00
Cyanide, Am. to Chlor.	NA	NA	NA	0.01	0.01	0.00
122 Lead	0.00	0.00	0.00	0.10	0.00	0.00
123 Mercury	I	I	I	0.81	0.47	0.50
124 Nickel	0.00	0.00	0.00	0.01	0.03	0.00
125 Selenium	NA	NA	NA	NA	NA	NA
126 Silver	0.00	0.00	0.00	0.01	0.00	0.01
128 Zinc	1100.	750.	440.	NA	133.	17.6
Aluminum	NA	NA	NA	NA	NA	NA
Ammonia	10.4	5.30	4.70	11.5	1.57	0.17
Iron	NA	NA	NA	NA	NA	NA
Manganese	0.11	3.42	4.65	2.09	0.17	0.21
Phenols, Total	0.003	NA	0.00	0.00	0.00	0.10
Oil & Grease	33.0	NA	26.0	7.77	6.00	0.00
Total Suspended Solids	97.0	100.	NA	414.	258.	545.
pH, Minimum	13.2	13.2	12.9	NA	NA	NA
pH, Maximum	13.5	13.2	13.4	NA	NA	NA

I-Interference
NA-Not Analyzed
* Less than 0.01

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Table V-77

POLLUTANT MASS LOADING IN THE ZINC
POWDER-GELLED AMALGAM ANODE ELEMENT
WASTE STREAM
(mg/kg)

POLLUTANTS/DAYS		Plant A			Plant B	
	1	2	3	1	2	3
Flow (l/kg)	0.23	0.21	0.31	0.65	1.08	1.67
Temperature (Deg C)	21.0	26.0	22.0	16.0	15.0	16.0
11 1,1,1-Trichloroethane	0.001	NA	0.01	0.001	0.00	0.00
13 1,1-Dichloroethane	NA	NA	NA	NA	NA	NA
29 1,1-Dichloroethylene	NA	NA	NA	NA	NA	NA
30 1,2-Trans-dichloroethylene	NA	NA	NA	NA	NA	NA
38 Ethylbenzene	NA	NA	NA	NA	NA	NA
44 Methylene chloride	0.00	NA	0.00	0.02	0.00	0.00
55 Naphthalene	NA	NA	NA	NA	NA	NA
64 Pentachlorophenol	0.00	0.00	0.00	0.03	0.00	0.00
66 Bis(2-ethylhexyl) phthalate	0.003	0.003	0.01	0.01	0.00	0.01
70 Diethyl phthalate	NA	NA	NA	NA	NA	NA
85 Tetrachloroethylene	NA	NA	NA	NA	NA	NA
86 Toluene	NA	NA	NA	NA	NA	NA
87 Trichloroethylene	0.001	NA	0.001	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00	0.00	0.00
115 Arsenic	0.24	0.22	0.26	0.00	0.09	0.12
118 Cadmium	0.02	0.03	0.02	0.04	0.01	0.01
119 Chromium, Total	0.00	0.01	0.02	0.01	0.02	0.01
Chromium, Hexavalent	0.00	0.00	I	0.00	0.00	I
120 Copper	0.15	0.12	0.20	0.07	0.09	0.09
121 Cyanide, Total	NA	NA	NA	NA	0.01	0.00
Cyanide, Amn. to Chlor.	NA	NA	NA	0.003	0.01	0.00
122 Lead	0.00	0.00	0.00	0.07	0.00	0.00
123 Mercury	I	I	I	0.53	0.51	0.83
124 Nickel	0.00	0.00	0.00	0.01	0.03	0.00
125 Selenium	NA	NA	NA	NA	NA	NA
126 Silver	0.00	0.00	0.00	0.01	0.002	0.02
128 Zinc	251.	159.	138.	NA	143.	29.4
Aluminum	NA	NA	NA	NA	NA	NA
Ammonia	2.40	1.12	1.50	7.47	1.69	0.28
Iron	NA	NA	NA	NA	NA	NA
Manganese	0.03	0.73	1.46	1.35	0.18	0.35
Phenols, Total	0.001	NA	0.00	0.00	0.00	0.16
Oil & Grease	7.52	NA	8.17	5.02	6.46	0.00
Total Suspended Solids	22.1	21.2	NA	267.	277.	909.
pH, Minimum	13.2	13.2	12.9	NA	NA	NA
pH, Maximum	13.5	13.2	13.4	NA	NA	NA

I-Interference
NA-Not Analyzed

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Table V-78

STATISTICAL ANALYSIS (mg/1) OF THE ZINC
POWDER-GELLED AMALGAM ANODE ELEMENT
WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median	# Val	# Zeros	# Pts
	Temperature (Deg C)	15.0	26.0	20.3	18.5	6	0	6
11	1,1,1-Trichloroethane	0.00	0.03	0.01	*	4	1	5
13	1,1-Dichloroethane	*	*	*	*	1	0	1
29	1,1-Dichloroethylene	NA	NA	NA	NA			
30	1,2-Trans-dichloroethylene	NA	NA	NA	NA			
38	Ethylbenzene	NA	NA	NA	NA			
44	Methylene chloride	0.00	0.02	*	0.00	1	4	5
55	Naphthalene	NA	NA	NA	NA			
64	Pentachlorophenol	0.00	0.04	*	0.00	1	5	6
66	Bis(2-ethylhexyl) phthalate	*	0.04	0.01	0.01	6	0	6
70	Diethyl phthalate	NA	NA	NA	NA			
85	Tetrachloroethylene	*	*	*	*	1	0	1
86	Toluene	*	*	*	*	1	0	1
87	Trichloroethylene	0.00	*	*	*	4	1	5
114	Antimony	NA	NA	NA	NA			
115	Arsenic	0.00	1.06	0.51	0.45	5	1	6
118	Cadmium	0.01	0.12	0.06	0.07	6	0	6
119	Chromium, Total	0.00	0.07	0.02	0.02	5	1	6
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	4	4
120	Copper	0.05	0.67	0.34	0.32	6	0	6
121	Cyanide, Total	0.00	0.01	0.00	0.00	2	1	3
	Cyanide, Amn. to Chlor.	0.00	0.01	0.00	0.00	2	1	3
122	Lead	0.00	0.10	0.02	0.00	1	5	6
123	Mercury	0.47	0.81	0.59	0.50	3	0	3
124	Nickel	0.00	0.03	0.01	0.00	2	4	6
125	Selenium	0.06	0.06	0.06	0.06	1	0	1
126	Silver	0.00	0.01	0.00	0.00	3	3	6
128	Zinc	17.6	1100.	488.	440.	5	0	5
	Aluminum	3.13	3.13	3.13	3.13	1	0	1
	Ammonia	0.17	11.5	5.61	5.00	6	0	6
	Iron	0.52	0.52	0.52	0.52	1	0	1
	Manganese	0.11	4.65	1.77	1.15	6	0	6
	Phenols, Total	0.00	0.10	0.02	0.00	2	3	5
	Oil & Grease	0.00	33.0	14.6	7.77	4	1	5
	Total Suspended Solids	97.0	545.	283.	258.	5	0	5
	pH, Minimum	12.9	13.2	13.1	13.2	3	0	3
	pH, maximum	13.2	13.5	13.4	13.4	3	0	3

NA-Not Analyzed
*-Less than 0.01

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Table V-79

STATISTICAL ANALYSIS (mg/kg) OF THE ZINC
POWDER-GELLED AMALGAM ANODE ELEMENT
WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median
	Flow (l/kg)	0.21	1.67	0.69	0.48
	Temperature (Deg C)	15.0	26.0	20.3	18.5
11	1,1,1-Trichloroethane	0.00	0.01	0.002	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	NA	NA	NA	NA
30	1,2-Trans-dichloroethylene	NA	NA	NA	NA
38	Ethylbenzene	NA	NA	NA	NA
44	Methylene chloride	0.00	0.02	0.00	0.00
55	Naphthalene	NA	NA	NA	NA
64	Pentachlorophenol	0.00	0.03	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.00	0.01	0.01	0.01
70	Diethyl phthalate	NA	NA	NA	NA
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	NA	NA	NA	NA
115	Arsenic	0.00	0.26	0.15	0.17
118	Cadmium	0.01	0.04	0.02	0.02
119	Chromium, Total	0.00	0.02	0.01	0.01
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.07	0.20	0.12	0.10
121	Cyanide, Total	0.00	0.01	0.002	0.001
	Cyanide, Am. to Chlor.	0.00	0.01	0.003	0.003
122	Lead	0.00	0.07	0.01	0.00
123	Mercury	0.51	0.83	0.62	0.53
124	Nickel	0.00	0.03	0.01	0.00
125	Selenium	0.04	0.04	0.04	0.04
126	Silver	0.00	0.02	0.01	0.001
128	Zinc	29.4	251.	144.	143.
	Aluminum	2.02	2.02	2.02	2.02
	Ammonia	0.28	7.47	2.40	1.58
	Iron	0.34	0.34	0.34	0.34
	Manganese	0.03	1.46	0.68	0.54
	Phenols, Total	0.00	0.17	0.03	0.00
	Oil & Grease	0.00	8.17	5.44	6.46
	Total Suspended Solids	21.2	909.	299.	267.
	pH, Minimum	12.9	13.2	13.1	13.1
	pH, Maximum	13.2	13.5	13.4	13.4

NA-Not Analyzed

Table V-80

POLLUTANT CONCENTRATIONS IN THE ZINC OXIDE
POWDER-PASTED OR PRESSED, REDUCED ANODE
ELEMENT WASTE STREAMS

		mg/l			
		Plant A		Plant B	
	POLLUTANTS		DAYS		
		2	3	1	2
	Temperature (Deg C)	15.0	13.0	15.0	10.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	*	*
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.08	0.11	0.00	0.00
118	Cadmium	0.07	0.06	0.01	0.03
119	Chromium, Total	0.03	0.06	0.00	0.00
	Chromium, Hexavalent	0.00	I	0.00	0.00
120	Copper	0.30	0.61	0.00	NA
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.08	0.14	0.00	NA
123	Mercury	0.10	0.16	0.00	0.01
124	Nickel	0.00	0.02	0.00	0.05
125	Selenium	0.00	0.00	0.00	0.00
126	Silver	0.12	0.27	0.00	0.00
128	Zinc	53.0	129.	0.28	2.84
	Aluminum	0.00	0.48	0.00	NA
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.01	0.01	0.00	0.00
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	122.	96.0	5.00	5.00
	pH, Minimum	11.9	11.4	9.4	9.4
	pH, Maximum	11.9	11.4	9.4	9.4

I-Interference
NA-Not Analyzed
*-Less than 0.01

Table V-81

POLLUTANT MASS LOADINGS IN THE ZINC OXIDE
POWDER-PASTED & PRESSED, REDUCED ANODE
ELEMENT WASTE STREAMS

	POLLUTANTS	Plant A		mg/kg	Plant B
				DAYS	
		2	3	1	2
	Flow (1/kg)	81.9	151.	315.	239.
	Temperature (Deg C)	15.0	13.0	15.0	10.0
11	1,1,1-Trichloroethane	0.00	0.02	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.03	0.02
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.01	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	6.56	16.7	0.00	0.00
118	Cadmium	5.82	8.78	3.47	8.13
119	Chromium, Total	2.05	8.93	0.00	0.00
	Chromium, Hexavalent	0.00	I	0.00	0.00
120	Copper	24.6	92.4	0.00	NA
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	6.39	21.2	0.00	NA
123	Mercury	8.20	24.2	0.00	3.35
124	Nickel	0.00	3.48	0.00	12.0
125	Selenium	0.00	0.00	0.00	0.00
126	Silver	9.83	40.9	0.00	0.00
128	Zinc	4340.	19500.	88.3	679.
	Aluminum	0.00	72.7	0.00	NA
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.82	0.91	0.00	0.00
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	10000.	14500.	1580.	1200.
	pH, Minimum	NA	NA	NA	NA
	pH, Maximum	NA	NA	NA	NA

I-Interference
NA-Not Analyzed

Table V-82

STATISTICAL ANALYSIS (mg/1) OF THE ZINC
OXIDE POWDER-PASTED OR PRESSED REDUCED
ANODE ELEMENT WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median	# Val	# Zeros	# Pts
	Temperature (Deg C)	10.0	15.0	12.9	14.0	4	0	4
11	1,1,1-Trichloroethane	0.00	*	*	0.00	1	3	4
13	1,1-Dichloroethane	0.00	*	*	*	2	2	4
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	4	4
44	Methylene chloride	0.00	*	*	0.00	1	3	4
55	Naphthalene	0.00	0.00	0.00	0.00	0	4	4
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	0.00	0.00	0.00	0	4	4
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	4	4
86	Toluene	0.00	*	*	*	2	2	4
87	Trichloroethylene	0.00	0.00	0.00	0.00	0	4	4
114	Antimony	0.00	0.00	0.00	0.00	0	4	4
115	Arsenic	0.00	0.11	0.05	0.04	2	2	4
118	Cadmium	0.01	0.07	0.04	0.05	4	0	4
119	Chromium, Total	0.00	0.06	0.02	0.02	2	2	4
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	3	3
120	Copper	0.00	0.61	0.30	0.30	2	1	3
121	Cyanide, Total	NA	NA	NA	NA			
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA			
122	Lead	0.00	0.14	0.07	0.08	2	1	3
123	Mercury	0.00	0.16	0.07	0.06	3	1	4
124	Nickel	0.00	0.05	0.02	0.01	2	2	4
125	Selenium	0.00	0.00	0.00	0.00	0	4	4
126	Silver	0.00	0.27	0.10	0.06	2	2	4
128	Zinc	0.28	129.	46.3	27.9	4	0	4
	Aluminum	0.00	0.48	0.16	0.00	1	2	3
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.00	0.01	0.00	0.00	2	2	4
	Phenols, Total	NA	NA	NA	NA			
	Oil & Grease	NA	NA	NA	NA			
	Total Suspended Solids	5.00	122.	57.0	50.5	4	0	4
	pH, Minimum	NA	NA	NA	NA			
	pH, Maximum	NA	NA	NA	NA			

NA-Not Analyzed
*-Less than 0.01
Number of values may include concentrations less than 0.005 shown as 0.00 on table.

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Table V-83

STATISTICAL ANALYSIS (mg/kg) OF THE ZINC
OXIDE POWDER-PASTED OR PRESSED, REDUCED
ANODE ELEMENT WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median
	Flow (1/kg)	81.9	315.	197.	195.
	Temperature (Deg C)	10.0	15.0	12.9	14.0
11	1,1,1-Trichloroethane	0.00	0.02	0.00	0.00
13	1,1-Dichloroethane	0.00	0.03	0.01	0.01
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.01	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	1.26	0.38	0.12
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	16.7	5.80	3.28
118	Cadmium	3.47	8.78	6.55	6.98
119	Chromium, Total	0.00	8.93	2.75	1.02
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.00	92.4	39.0	24.6
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.00	21.2	9.20	6.39
123	Mercury	0.00	24.2	8.94	5.77
124	Nickel	0.00	12.0	3.86	1.74
125	Selenium	0.00	0.00	0.00	0.00
126	Silver	0.00	40.9	12.7	4.92
128	Zinc	88.3	19500.	6160.	2510.
	Aluminum	0.00	72.7	24.2	0.00
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.00	0.91	0.43	0.41
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	1200.	14500.	6830.	5790.
	pH, Minimum	9.4	11.9	10.5	10.4
	pH, Maximum	9.4	11.9	10.5	10.4

NA-Not Analyzed

Table V-84

POLLUTANT CONCENTRATIONS IN THE ZINC
ELECTRODEPOSITED ANODE ELEMENT WASTE
STREAMS (Plant A)

mg/l

	POLLUTANTS	DAYS		
		1	2	3
	Temperature (Deg C)	9.0	10.0	7.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.00
119	Chromium, Total	0.02	0.02	0.01
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.01	0.02	0.01
121	Cyanide, Total	0.01	0.01	0.01
	Cyanide, Amn. to Chlor.	0.01	0.01	0.01
122	Lead	0.04	0.00	0.01
123	Mercury	30.8	0.00	13.3
124	Nickel	0.01	0.00	0.00
125	Selenium	0.00	0.00	0.00
126	Silver	0.07	0.03	0.43
128	Zinc	12.1	12.2	12.4
	Aluminum	0.00	0.00	0.00
	Ammonia	1.40	0.28	0.28
	Iron	NA	NA	NA
	Manganese	0.00	0.00	0.00
	Phenols, Total	0.01	0.00	0.00
	Oil & Grease	1.00	7.60	4.10
	Total Suspended Solids	10.1	10.0	3.40
	pH, Minimum	NA	NA	NA
	pH, Maximum	NA	NA	NA

NA-Not Analyzed
*-Less than 0.005

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Table V-85

POLLUTANT MASS LOADINGS IN THE ZINC
ELECTRODEPOSITED ANODE ELEMENT WASTE
STREAMS (Plant A)

mg/kg

	POLLUTANTS	DAYS		
		1	2	3
	Flow (l/kg)	4660.	5370.	4870.
	Temperature (Deg C)	9.0	10.0	7.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.47	0.54	0.49
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	2.44
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.02
119	Chromium, Total	72.7	32.2	61.9
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	55.7	107.	39.6
121	Cyanide, Total	46.6	26.8	24.4
	Cyanide, Amn. to Chlor.	23.3	26.8	24.4
122	Lead	184.	0.00	35.5
123	Mercury	143000.	0.00	65100.
124	Nickel	23.9	0.00	19.7
125	Selenium	0.00	0.00	0.00
126	Silver	303.	166.	2100.
128	Zinc	56600.	65500.	60600.
	Aluminum	0.80	0.00	0.97
	Ammonia	6520.	1503.	1360.
	Iron	NA	NA	NA
	Manganese	2.27	0.00	2.12
	Phenols, Total	32.6	5.37	4.87
	Oil & Grease	4660.	40800.	20000.
	Total Suspended Solids	47000.	53700.	16600.
	pH, Minimum	NA	NA	NA
	pH, Maximum	NA	NA	NA

NA-Not Analyzed

Table V-86

NORMALIZED FLOWS OF POST-FORMATION
RINSE WASTE STREAMS

Waste Stream	Plant ID#	l/kg	Plant Mean
Post-formation Rinsing	A	79.7*	
	A	1135.5*[1]	
	A	100.9*	90.3
	B	262.6	
	B	341.8	302.2
	C	+	
	(Mean		196.25)
	(Median		196.25)

* This flow rate reflects the combined wastewater from post-formation rinsing, floor area maintenance, and lab analysis.

+ Data not provided in survey

[1] Value for this day eliminated from statistical analysis because of extreme variablility in floor area maintenance water use.

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Table V-87

POLLUTANT CONCENTRATIONS IN THE SILVER
POWDER PRESSED AND ELECTROLYTICALLY
OXIDIZED ELEMENT WASTE STREAMS

	POLLUTANTS	Plant A		mg/l Days	Plant B	
		1	2	3	1	3
	Temperature (Deg C)	14.0	15.0	15.0	15.0	15.0
11	1,1,1-Trichloroethane	0.00	0.00	*	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0.00
86	Toluene	0.00	*	0.00	*	*
87	Trichloroethylene	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00
115	Arsenic	0.11	0.00	0.00	0.00	0.00
118	Cadmium	0.08	0.01	0.07	0.06	0.00
119	Chromium, Total	0.01	0.01	11.6	0.00	0.00
	Chromium, Hexavalent	I	0.00	0.00	0.00	0.00
120	Copper	1.21	4.11	4.73	0.00	0.00
121	Cyanide, Total	NA	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA	NA
122	Lead	0.69	0.20	0.82	0.00	0.00
123	Mercury	0.06	0.01	0.01	0.01	0.07
124	Nickel	0.25	0.05	0.59	0.05	0.00
125	Selenium	0.00	0.00	0.00	0.00	0.00
126	Silver	0.64	0.32	1.48	3.88	3.20
128	Zinc	235.	29.4	59.0	0.00	0.00
	Aluminum	0.00	0.00	4.44	0.00	0.00
	Ammonia	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA
	Manganese	0.01	0.02	0.04	0.00	0.01
	Phenols, Total	NA	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA	NA
	Total Suspended Solids	362.	86.0	217.	5.00	49.0
	pH, Minimum	10.6	11.8	10.6	11.0	10.8
	pH, Maximum	11.8	11.8	10.6	11.0	11.0

NA-Not Analyzed
*-Less than 0.01

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Table V-88

POLLUTANT MASS LOADINGS IN THE SILVER
POWDER PRESSED AND ELECTROLYTICALLY
OXIDIZED CATHODE ELEMENT WASTE STREAMS

POLLUTANTS		Plant A	mg/kg Days		Plant B	
		1	2	3	1	3
	Flow (1/kg)	79.7	1140.	101.	263.	342.
	Temperature (Deg C)	14.0	15.0	15.0	15.0	15.0
11	1,1,1-Trichloroethane	0.00	0.11	0.06	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.03	0.03
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	*	0.11	0.01	0.00	0.00
55	Naphthalene	0.04	0.57	0.51	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA	NA
70	Diethyl phthalate	0.04	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0.00
86	Toluene	0.00	2.27	0.00	0.26	0.68
87	Trichloroethylene	0.01	0.11	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00	0.00
115	Arsenic	8.77	0.00	0.00	0.00	0.00
118	Cadmium	6.53	9.08	6.56	14.4	1.37
119	Chromium, Total	0.56	7.95	1170.	0.00	0.00
	Chromium, Hexavalent	I	0.00	0.00	0.00	0.00
120	Copper	96.4	4670.	477.	0.00	0.00
121	Cyanide, Total	NA	NA	NA	NA	NA
	Cyanide, Am. to Chlor.	NA	NA	NA	NA	NA
122	Lead	55.0	227.	82.8	0.00	0.00
123	Mercury	4.78	10.2	1.72	2.89	24.3
124	Nickel	19.9	56.8	59.6	12.6	0.00
125	Selenium	0.00	0.00	0.00	0.00	0.00
126	Silver	51.0	363.	149.	1020.	1090.
128	Zinc	18700.	33400.	5960.	0.00	0.00
	Aluminum	0.00	0.00	488.	0.00	0.00
	Ammonia	NA	NA	NA	NA	NA
	Iron	NA	NA	NA	NA	NA
	Manganese	0.72	27.3	4.04	0.00	2.74
	Phenols, Total	NA	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA	NA
	Total Suspended Solids	28800.	97700.	21900.	1310.	16700.
	pH, Minimum	10.6	11.8	10.6	11.0	10.8
	pH, Maximum	11.8	11.8	10.6	11.0	11.0

I-Interference
NA-Not Analyzed

Table V-89

STATISTICAL ANALYSIS (mg/l) OF THE SILVER
POWDER PRESSED AND ELECTROLYTICALLY
OXIDIZED CATHODE ELEMENT WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median	# Val	# Zeros	# Pts
	Temperature (Deg C)	14.0	15.0	15.0	15.0	5	0	5
11	1,1,1-Trichloroethane	0.00	*	*	0.00	2	3	5
13	1,1-Dichloroethane	0.00	*	*	0.00	2	3	5
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00	0	5	5
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	5	5
38	Ethylbenzene	0.00	0.00	0.00	0.00	0	5	5
44	Methylene chloride	0.00	*	*	*	3	2	5
55	Naphthalene	0.00	*	*	*	3	2	5
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	*	*	0.00	1	4	5
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	5	5
86	Toluene	0.00	*	*	*	3	2	5
87	Trichloroethylene	0.00	*	*	0.00	2	3	5
114	Antimony	0.00	0.00	0.00	0.00	0	5	5
115	Arsenic	0.00	0.11	0.02	0.00	1	4	5
118	Cadmium	0.00	0.08	0.04	0.06	5	0	5
119	Chromium, Total	0.00	11.6	2.32	0.01	3	2	5
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	4	4
120	Copper	0.00	4.73	2.01	1.21	3	2	5
121	Cyanide, Total	NA	NA	NA	NA			
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA			
122	Lead	0.00	0.82	0.34	0.20	3	2	5
123	Mercury	0.01	0.07	0.03	0.02	5	0	5
124	Nickel	0.00	0.59	0.19	0.05	4	1	5
125	Selenium	0.00	0.00	0.00	0.00	0	5	5
126	Silver	0.32	3.88	1.90	1.48	5	0	5
128	Zinc	0.00	235.	64.7	29.4	3	2	5
	Aluminum	0.00	4.44	0.89	0.00	1	4	5
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.00	0.04	0.02	0.01	4	1	5
	Phenols, Total	NA	NA	NA	NA			
	Oil & Grease	NA	NA	NA	NA			
	Total Suspended Solids	5.00	362.	144.	86.0	5	0	5
	pH, Minimum	10.6	11.8	11.0	10.8	5	0	5
	pH, Maximum	10.6	11.8	11.2	11.0	5	0	5

NA-Not Analyzed
*-Less than 0.01

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Table V-90

STATISTICAL ANLYSIS (mg/kg) OF THE SILVER
POWDER PRESSED AND ELECTROLYTICALLY
OXIDIZED CATHODE ELEMENT WASTE STREAMS

POLLUTANTS

		Minimum	Maximum	Mean	Median
	Flow (l/kg)	79.7	1135.5	384.1	262.6
	Temperature (Deg C)	14.0	15.0	15.0	15.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	8.77	1.75	0.00
118	Cadmium	1.37	14.4	7.60	6.56
119	Chromium, Total	0.00	1170.	236.	0.56
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.00	4670.	1050.	96.4
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.00	227.	73.0	55.0
123	Mercury	1.72	24.3	8.78	4.78
124	Nickel	0.00	59.6	29.8	19.9
125	Selenium	0.00	0.00	0.00	0.00
126	Silver	51.0	1090.	535.	363.
128	Zinc	0.00	33400.	11600.	5960.
	Aluminum	0.00	448.	89.6	0.00
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.00	27.3	6.95	2.74
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	1310.	97700.	33300.	21900.
	pH, Minimum	10.6	11.8	11.0	10.8
	pH, Maximum	10.6	11.8	11.2	11.0

NA-Not Analyzed

TABLE V-91

POLLUTANT CONCENTRATIONS IN THE SILVER OXIDE (Ag₂O) POWDER-THERMALLY REDUCED AND SINTERED, ELECTROLYTICALLY FORMED CATHODE ELEMENT WASTE STREAMS
(Plant B)

	mg/l Days	
POLLUTANTS	2	3
Temperature (Deg C)	10.0	16.0
11 1,1,1-Trichloroethane	0.00	0.00
13 1,1-Dichloroethane	*	0.00
29 1,1-Dichloroethylene	*	*
30 1,2-Trans-dichloroethylene	0.00	0.00
38 Ethylbenzene	0.00	0.00
44 Methylene chloride	*	0.00
55 Naphthalene	*	*
64 Pentachlorophenol	NA	NA
66 Bis(2-ethylhexyl) phthalate	NA	NA
70 Diethyl phthalate	*	*
85 Tetrachloroethylene	0.00	0.00
86 Toluene	0.00	0.00
87 Trichloroethylene	0.00	0.00
114 Antimony	0.00	0.00
115 Arsenic	0.00	0.00
118 Cadmium	0.00	0.00
119 Chromium, Total	0.01	0.01
Chromium, Hexavalent	0.00	0.00
120 Copper	0.00	0.00
121 Cyanide, Total	0.01	0.00
Cyanide, Amn. to Chlor.	0.01	0.01
122 Lead	0.00	0.00
123 Mercury	0.01	0.02
124 Nickel	0.00	0.00
125 Selenium	0.00	0.00
126 Silver	0.30	16.7
128 Zinc	0.02	0.01
Aluminum	0.35	0.00
Ammonia	0.84	0.28
Iron	NA	NA
Manganese	0.00	0.00
Phenols, Total	0.00	0.02
Oil & Grease	12.0	9.30
Total Suspended Solids	6.10	1.00
pH, Minimum	12.4	9.0
pH, Maximum	12.4	9.0

NA-Not Analyzed
*-Less than 0.01

Table V-92

POLLUTANT MASS LOADINGS IN THE SILVER
OXIDE (Ag_2O) POWDER-THERMALLY REDUCED
AND SINTERED, ELECTROLYTICALLY FORMED
CATHODE ELEMENT WASTE STREAMS
(Plant B)

	POLLUTANTS	mg/kg Days	
		2	3
	Flow (1/kg)	437.4	100.9
	Temperature (Deg C)	10.0	16.0
11	1,1,1-Trichloroethane	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00
29	1,1-Dichloroethylene	0.04	0.01
30	1,2-Trans-dichloroethylene	0.00	0.00
38	Ethylbenzene	0.00	0.00
44	Methylene chloride	0.00	0.00
55	Naphthalene	0.00	0.00
64	Pentachlorophenol	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA
70	Diethyl phthalate	0.00	0.00
85	Tetrachloroethylene	0.00	0.00
86	Toluene	0.00	0.00
87	Trichloroethylene	0.00	0.00
114	Antimony	0.00	0.00
115	Arsenic	0.00	0.00
118	Cadmium	0.00	0.00
119	Chromium, Total	4.37	0.71
	Chromium, Hexavalent	0.00	0.00
120	Copper	0.88	0.00
121	Cyanide, Total	2.62	0.51
	Cyanide, Amn. to Chlor.	2.19	0.51
122	Lead	0.00	0.00
123	Mercury	5.69	2.02
124	Nickel	0.00	0.00
125	Selenium	0.00	0.00
126	Silver	131.	1690.
128	Zinc	7.44	1.11
	Aluminum	153.	0.00
	Ammonia	367.	28.3
	Iron	NA	NA
	Manganese	0.00	0.00
	Phenols, Total	1.75	1.72
	Oil & Grease	5250.	939.
	Total Suspended Solids	2670.	101.
	pH, Minimum	12.4	9.0
	pH, Maximum	12.4	9.0

NA-Not Analyzed

Table V-93

POLLUTANT CONCENTRATIONS IN THE SILVER PEROXIDE (AgO) POWDER CATHODE ELEMENT WASTE STREAMS

POLLUTANTS	Plant C	mg/l Plant B Days 1	2	3
Temperature (Deg C)	38.0	NA	NA	NA
11 1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13 1,1-Dichloroethane	0.00	0.00	0.00	0.00
29 1,1-Dichloroethylene	*	0.00	0.00	0.00
30 1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38 Ethylbenzene	0.00	0.00	0.00	0.00
44 Methylene chloride	0.00	*	*	0.00
55 Naphthalene	*	*	0.00	0.00
64 Pentachlorophenol	NA	NA	NA	NA
66 Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70 Diethyl phthalate	*	0.00	0.00	0.00
85 Tetrachloroethylene	0.00	0.00	0.00	0.00
86 Toluene	0.00	0.00	0.00	0.00
87 Trichloroethylene	0.00	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00
115 Arsenic	0.00	5.75	3.95	3.38
118 Cadmium	0.00	5.99	2.25	3.38
119 Chromium, Total	0.01	0.22	0.09	0.16
Chromium, Hexavalent	0.00	I	I	I
120 Copper	0.01	0.00	0.00	0.00
121 Cyanide, Total	0.01	NA	NA	NA
Cyanide, Amn. to Chlor.	0.01	NA	NA	NA
122 Lead	0.00	0.00	0.00	0.00
123 Mercury	0.01	I	I	I
124 Nickel	0.01	0.00	0.00	0.00
125 Selenium	0.00	3.87	2.87	2.20
126 Silver	45.2	71.0	48.6	8.80
128 Zinc	0.45	0.01	0.05	0.03
Aluminum	0.00	0.00	0.00	3.56
Ammonia	1.10	NA	NA	NA
Iron	NA	NA	NA	NA
Manganese	0.00	0.00	0.00	0.00
Phenols, Total	0.00	NA	NA	NA
Oil & Grease	16.0	NA	NA	NA
Total Suspended Solids	620.	310.	178.	730.
pH, Minimum	NA	NA	NA	NA
pH, Maximum	NA	NA	NA	NA

I-Interference
NA-Not Analyzed
*-Less than 0.01

Table V-94

POLLUTANT MASS LOADINGS IN THE SILVER
PEROXIDE (AgO) POWDER CATHODE ELEMENT
WASTE STREAMS

POLLUTANTS	Plant C 541	mg/kg Days 1	Plant B 2	3
Flow (l/kg)	75.7	5.54	22.4	10.4
Temperature (Deg C)	38.0	NA	NA	NA
11 1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13 1,1-Dichloroethane	0.00	0.00	0.00	0.00
29 1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30 1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38 Ethylbenzene	0.00	0.00	0.00	0.00
44 Methylene chloride	0.00	0.00	0.00	0.00
55 Naphthalene	0.00	0.00	0.00	0.00
64 Pentachlorophenol	NA	NA	NA	NA
66 Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70 Diethyl phthalate	0.00	0.00	0.00	0.00
85 Tetrachloroethylene	0.00	0.00	0.00	0.00
86 Toluene	0.00	0.00	0.00	0.00
87 Trichloroethylene	0.00	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00
115 Arsenic	0.00	31.8	88.3	35.2
118 Cadmium	0.00	33.2	50.3	35.2
119 Chromium, Total	0.61	1.22	1.97	1.67
Chromium, Hexavalent	0.00	I	I	I
120 Copper	0.98	0.00	0.00	0.00
121 Cyanide, Total	0.53	NA	NA	NA
Cyanide, Amn. to Chlor.	0.38	NA	NA	NA
122 Lead	0.00	0.00	0.00	0.00
123 Mercury	0.53	I	I	I
124 Nickel	0.61	0.00	0.00	0.00
125 Selenium	0.00	21.4	64.1	22.9
126 Silver	3420.	393.	1090.	91.7
128 Zinc	34.1	0.08	1.12	0.31
Aluminum	0.00	0.00	0.00	37.1
Ammonia	83.3	NA	NA	NA
Iron	NA	NA	NA	NA
Manganese	0.00	0.00	0.00	0.00
Phenols, Total	0.08	NA	NA	NA
Oil & Grease	1210.	NA	NA	NA
Total Suspended Solids	46900.	1720.	3980.	7610.
pH, Minimum	9.0	10.0	11.0	10.0
pH, Maximum	9.0	11.0	13.0	13.0

I-Interference
NA-Not Analyzed

Table V-95

STATISTICAL ANALYSIS (mg/1) OF THE SILVER
PEROXIDE (AgO) POWDER CATHODE ELEMENT
WASTE STREAMS

POLLUTANTS	Minimum	Maximum	Mean	Median	# Val	# Zeros	# Pts
Flow							
Temperature (Deg C)	38.0	38.0	38.0	38.0	1	0	1
11 1,1,1-Trichloroethane	0.00	*	*	0.00	1	3	4
13 1,1-Dichloroethane	0.00	0.00	0.00	0.00	0	4	4
29 1,1-Dichloroethylene	0.00	*	*	0.00	1	3	4
30 1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
38 Ethylbenzene	0.00	0.00	0.00	0.00	0	4	4
44 Methylene chloride	0.00	*	*	*	2	2	4
55 Naphthalene	0.00	*	*	*	2	2	4
64 Pentachlorophenol	NA	NA	NA	NA			
66 Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA			
70 Diethyl phthalate	0.00	*	*	0.00	1	3	4
85 Tetrachloroethylene	0.00	0.00	0.00	0.00	0	4	4
86 Toluene	0.00	0.00	0.00	0.00	0	4	4
87 Trichloroethylene	0.00	0.00	0.00	0.00	0	4	4
114 Antimony	0.00	0.00	0.00	0.00	0	4	4
115 Arsenic	0.00	5.75	3.27	3.67	3	1	4
118 Cadmium	0.00	5.99	2.91	2.82	3	1	4
119 Chromium, Total	0.01	0.22	0.12	0.12	4	0	4
Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	1	1
120 Copper	0.00	0.01	0.00	0.00	1	3	4
121 Cyanide, Total	0.01	0.01	0.01	0.01	1	0	1
Cyanide, Amn. to Chlor.	0.01	0.01	0.01	0.01	1	0	1
122 Lead	0.00	0.00	0.00	0.00	0	4	4
123 Mercury	0.01	0.01	0.01	0.01	1	0	1
124 Nickel	0.00	0.01	0.00	0.00	1	3	4
125 Selenium	0.00	3.87	2.24	2.54	3	1	4
126 Silver	8.80	71.0	43.4	46.9	4	0	4
128 Zinc	0.01	0.45	0.14	0.04	4	0	4
Aluminum	0.00	3.56	0.89	0.00	1	3	4
Ammonia	1.10	1.10	1.10	1.10	1	0	1
Iron	NA	NA	NA	NA			
Manganese	0.00	0.00	0.00	0.00	0	4	4
Phenols, Total	0.00	0.00	0.00	0.00	1	0	1
Oil & Grease	16.0	16.0	16.0	16.0	1	0	1
Total Suspended Solids	178.	730.	460.	465.	4	0	4
pH, Minimum	9.0	11.0	10.0	10.0	4	0	4
pH, Maximum	9.0	13.0	11.5	12.0	4	0	4

NA-Not Analyzed
*-Less than 0.01

Number of values may include concentrations less than 0.005 shown as 0.00 on table.

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Table V-96

STATISTICAL ANALYSIS (mg/kg) OF THE SILVER PEROXIDE (AgO) POWDER CATHODE ELEMENT WASTE STREAMS

	POLLUTANTS	Minimum	Maximum	Mean	Median
	Flow (1)	5.54	75.7	28.5	16.4
	Temperature (Deg C)	38.0	38.0	38.0	38.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	88.3	38.8	33.5
118	Cadmium	0.00	50.3	29.7	34.2
	Chromium, Total	0.61	1.97	1.37	1.44
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.00	0.98	0.25	0.00
121	Cyanide, Total	0.53	0.53	0.53	0.53
	Cyanide, Amn. to Chlor.	0.38	0.38	0.38	0.38
122	Lead	0.00	0.00	0.00	0.00
123	Mercury	0.53	0.53	0.53	0.53
124	Nickel	0.00	0.61	0.15	0.00
125	Selenium	0.00	64.1	27.1	22.2
126	Silver	91.7	3420.	1250.	740.
128	Zinc	0.08	34.1	8.89	0.72
	Aluminum	0.00	37.1	9.27	0.00
	Ammonia	83.3	83.3	83.3	83.3
	Iron	NA	NA	NA	NA
	Manganese	0.00	0.00	0.00	0.00
	Phenols, Total	0.08	0.08	0.08	0.08
	Oil & Grease	1210.	1210.	1210.	1200.
	Total Suspended Solids	1720.	46900.	15100.	5790.
	pH, Minimum	9.0	11.0	10.0	10.0
	pH, Maximum	9.0	13.0	11.5	12.0

NA—Not Analyzed

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Table V-97

PRODUCTION NORMALIZED DISCHARGES FROM
CELL WASH ELEMENTS

WASTE STREAM	PLANT ID #	DCP DATA 1/kg	MEAN SAMPLING DATA 1/kg
Cell Wash	A		0.09
Wastewater	B	4.6	
	C	5.0	
	D	34.1	
	E		0.34
	F	0.33	
	G		0.21
	RANGE 1/kg	MEAN 1/kg	MEDIAN 1/kg
	0.09- 34.1	6.35	0.34

TABLE V-98

POLLUTANT CONCENTRATIONS IN THE CELL WASH
ELEMENT WASTE STREAMS

mg/l

POLLUTANTS	Plant G 1	2	3	Plant E DAYS 1	2	3	Plant A 1	2	3	Plant C 1	2	3
Temperature (Deg C)	29.8	30.3	31.1	NA	58.0	56.0	34.0	34.0	34.0	NA	NA	NA
11 1,1,1 - Trichloroethane	0.01	*	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13 1,1 - Dichloroethane	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	*	0.00
29 1,1 - Dichloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	*	*	0.00
30 1,2 - Trans-dichloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
38 Ethylbenzene	NA	NA	NA	0.00	*	0.00	NA	NA	NA	0.00	0.00	0.00
44 Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55 Naphthalene	NA	NA	NA	0.00	0.02	*	NA	NA	NA	0.00	0.00	0.00
64 Pentachlorophenol	0.00	NA	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
66 Bis(2-ethylhexyl) phthalate	0.04	0.11	0.02	NA	NA	NA	0.16	0.06	0.03	NA	NA	NA
70 Diethyl phthalate	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
85 Tetrachloroethylene	NA	NA	NA	0.00	0.00	0.00	• NA	NA	NA	0.00	0.00	0.00
86 Toluene	NA	NA	NA	0.00	*	0.00	NA	NA	NA	0.00	0.00	0.00
87 Trichloroethylene	0.01	*	*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115 Arsenic	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	2.50	2.53	3.45
118 Cadmium	0.00	0.00	0.01	0.01	0.18	0.01	0.01	0.01	0.01	0.10	0.10	0.12
119 Chromium, Total	0.03	0.04	0.15	9.68	73.1	15.4	256.	253.	318.	0.03	0.00	0.03
Chromium, Hexavalent	0.00	0.00	0.00	8.60	59.1	15.0	I	I	I	0.00	0.00	0.00
120 Copper	0.27	0.28	0.63	0.03	0.19	0.01	0.37	0.54	0.43	0.10	0.08	0.12
121 Cyanide, Total	NA	NA	NA	0.01	0.02	0.02	3.90	7.20	2.10	NA	NA	NA
Cyanide, Amn. to Chlor.	NA	NA	NA	I	I	I	3.90	4.90	2.10	NA	NA	NA
122 Lead	0.01	0.02	0.14	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
123 Mercury	0.02	0.02	0.29	0.97	5.34	1.33	I	I	I	0.20	0.59	0.41
124 Nickel	3.82	6.49	24.4	0.21	1.54	0.35	4.68	8.64	6.86	0.88	0.69	1.05
125 Selenium	NA	NA	NA	0.00	0.05	0.00	NA	NA	NA	1.71	1.63	2.01
126 Silver	0.00	0.00	0.00	0.02	1.35	0.03	0.01	0.02	0.01	0.49	0.26	0.26
128 Zinc	3.67	3.68	12.4	0.43	12.7	0.71	18.4	32.9	29.4	1.90	2.22	1.44
Aluminum	NA	NA	NA	0.00	0.17	0.00	NA	NA	NA	0.00	0.00	0.00
Ammonia	1.46	8.37	2.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	17.6	24.0	69.6	0.07	0.61	0.15	14.8	38.4	25.2	0.06	0.09	0.06
Phenols, Total	0.02	0.02	0.01	0.09	0.02	0.02	0.00	0.00	0.00	NA	NA	NA
Oil & Grease	41.4	71.6	49.8	3.00	29.7	11.0	104.	205.	134.	NA	NA	NA
Total Suspended Solids	21.6	51.9	161.	33.0	13.7	0.00	29.0	38.0	42.0	29.5	34.3	28.7
pH, minimum	8.9	8.0	9.7	NA	NA	NA	5.8	6.4	5.8	8.0	7.5	7.5
pH, maximum	11.4	11.0	11.9	NA	NA	NA	5.8	6.4	5.8	11.5	11.9	12.0

I - Interference
NA - Not Analyzed
* - Less than 0.01

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TABLE V-99

POLLUTANT MASS LOADINGS IN THE CELL WASH
ELEMENT WASTE STREAMS   mg/l

POLLUTANTS	Plant G			Plant E DAYS			Plant A			Plant C		
	1	2	3	1	2	3	1	2	3	1	2	3
Flow (l/kg)	0.19	0.22	0.22	0.58	0.30	0.60	0.09	0.09	0.09	1.48	1.56	1.80
Temperature (Deg C)	29.9	30.3	31.1	NA	58.0	56.0	34.0	34.0	34.0	NA	NA	NA
11 1,1,1 - Trichloroethane	0.002	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13 1,1 - Dichloroethane	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
29 1,1 - Dichloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.01	0.00	0.00
30 1,2 - Trans-dichloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
38 Ethylbenzene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
44 Methylene chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55 Naphthalene	NA	NA	NA	0.00	0.07	0.00	NA	NA	NA	0.00	0.00	0.00
64 Pentachlorophenol	0.00	NA	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
66 Bis(2-ethylhexyl) phthalate	0.01	0.03	0.01	NA	NA	NA	0.01	0.01	0.005	NA	NA	NA
70 Diethyl phthalate	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
85 Tetrachloroethylene	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	0.00
86 Toluene	NA	NA	NA	0.00	0.001	0.00	NA	NA	NA	0.00	0.00	0.00
87 Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115 Arsenic	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	3.71	3.95	6.23
118 Cadmium	0.001	0.00	0.002	0.01	0.05	0.01	0.001	0.001	0.001	0.15	0.16	0.22
119 Chromium, Total	0.01	0.01	0.03	5.57	21.6	9.29	21.8	22.6	28.6	0.04	0.003	0.05
Chromium, Hexavalent	0.00	0.00	0.00	4.95	17.4	9.05	I	I	I	0.00	0.00	0.00
120 Copper	0.05	0.06	0.14	0.02	0.06	0.06	0.03	0.05	0.04	0.15	0.12	0.22
121 Cyanide, Total	NA	NA	NA	0.08	0.01	0.01	0.33	0.64	0.19	NA	NA	NA
Cyanide, Am. to Chlor.	NA	NA	NA	I	I	I	0.33	0.44	0.19	NA	NA	NA
122 Lead	0.002	0.01	0.03	0.00	0.003	0.00	0.00	0.00	0.00	0.00	0.00	0.00
123 Mercury	0.004	0.01	0.07	0.56	1.58	0.80	I	I	I	0.30	0.92	0.74
124 Nickel	0.74	1.46	5.37	0.12	0.45	0.21	0.40	0.77	0.62	1.31	1.07	1.90
125 Selenium	NA	NA	NA	0.00	0.01	0.00	NA	NA	NA	2.54	2.55	3.76
126 Silver	0.00	0.00	0.00	0.01	0.40	0.02	0.001	0.001	0.001	0.73	0.41	0.47
128 Zinc	0.71	0.83	2.73	0.25	3.76	0.43	1.57	2.94	2.64	2.82	3.46	2.59
Aluminum	NA	NA	NA	0.00	0.05	0.00	NA	NA	NA	0.00	0.00	0.00
Ammonia	0.28	1.88	0.50	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00
Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	3.42	5.39	15.3	0.04	0.18	0.09	1.26	3.43	2.26	0.09	0.15	0.11
Phenols, Total	0.003	0.004	0.003	0.05	0.01	0.01	0.00	0.00	0.00	NA	NA	NA
Oil & Grease	8.02	16.1	11.0	1.73	8.77	6.64	8.86	18.3	12.0	NA	NA	NA
Total Suspended Solids	4.19	11.6	35.5	19.0	4.05	0.00	2.47	3.39	3.77	43.7	53.6	51.7
pH, minimum	8.9	8.0	9.7	NA	NA	NA	5.8	6.4	5.8	8.0	7.5	7.5
pH, maximum	11.4	11.0	11.9	NA	NA	NA	5.8	6.4	5.8	11.5	11.9	12.0

I - Interference
NA - Not Analyzed

Table V-100

STATISTICAL ANALYSIS (mg/l) OF THE CELL
WASH WASTE STREAMS

	POLLUTANTS	MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	29.9	58.0	32.3	34.0	8	0	8
11	1,1,1 - Trichloroethane	0.00	0.02	*	*	9	3	12
13	1,1 - Dichloroethane	0.00	*	*	*	4	2	6
29	1,1 - Dichloroethylene	0.00	*	*	*	4	2	6
30	1,2 - Trans-dichloroethylene	.00	*	*	*	3	3	6
38	Ethylbenzene	0.00	*	*	0.00	1	5	6
44	Methylene chloride	0.00	*	*	0.00	4	8	12
55	Naphthalene	0.00	0.02	*	*	5	1	6
64	Pentachlorophenol	0.00	0.00	0.00	0.00	0	2	2
66	Bis(2-ethylhexyl) phthalate	0.02	0.16	0.07	0.05	6	0	6
70	Diethyl phthalate	*	*	*	*	6	0	6
85	Tetrachloroethylene	0.00	*	*	*	3	3	6
86	Toluene	0.00	*	*	0.00	1	5	6
87	Trichloroethylene	0.00	0.01	*	*	8	4	12
114	Antimony	0.00	0.00	0.00	0.00	0	12	12
115	Arsenic	0.00	3.45	0.71	0.00	4	8	12
118	Cadmium	0.00	0.18	0.05	0.01	12	0	12
119	Chromium, Total	0.00	318.	77.1	4.91	12	0	12
	Chromium, Hexavalent	0.00	59.1	9.19	0.00	3	6	9
120	Copper	0.01	0.63	0.25	0.23	12	0	12
121	Cyanide, Total	0.01	7.20	2.21	1.06	6	0	6
	Cyanide, Amn. to Chlor.	2.10	4.90	3.63	3.90	3	0	3
122	Lead	0.00	0.14	0.02	0.00	4	8	12
123	Mercury	0.02	5.34	1.02	0.41	9	0	9
124	Nickel	0.21	24.4	4.97	2.68	12	0	12
125	Selenium	0.00	2.08	0.91	0.84	4	2	6
126	Silver	0.00	1.35	0.20	0.02	9	3	12
128	Zinc	0.43	32.9	9.99	3.67	12	0	12
	Aluminum	0.00	0.17	0.03	0.00	1	5	6
	Ammonia	1.46	8.37	4.02	2.25	3	0	3
	Iron	NA	NA	NA	NA			
	Manganese	0.06	69.6	15.9	7.70	12	0	12
	Phenols, Total	0.00	0.09	0.02	0.01	6	3	9
	Oil & Grease	3.00	205.	72.2	49.8	9	0	9
	Total Suspended Solids	0.00	161.	40.2	31.2	11	1	12
	pH, minimum	5.8	9.7	7.5	7.5	9	0	9
	pH, maximum	5.8	12.0	9.7	11.4	9	0	9

NA - Not Analyzed
 * - Less than 0.01
Number of values may include concentrations less than 0.005
shown as 0.00 on table.

Table V-101

STATISTICAL ANALYSIS (mg/kg) OF THE
CELL WASH WASTE STREAMS

POLLUTANTS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (1/kg)	0.09	1.80	0.60	0.26
	Temperature (Deg C)	29.9	58.0	32.3	34.0
11	1,1,1 - Trichloroethane	0.00	0.01	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.01	0.00	0.00
64	Pentachlorophenol	0.00	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.003	0.03	0.01	0.01
70	Diethyl phthalate	0.00	0.001	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.002	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	6.23	1.16	0.00
118	Cadmium	0.00	0.22	0.05	0.003
119	Chromium, Total	0.003	28.6	9.13	2.81
	Chromium, Hexavalent	0.00	17.4	3.49	0.00
120	Copper	0.01	0.22	0.08	0.05
121	Cyanide, Total	0.01	0.64	0.20	0.10
	Cyanide, Amn. to Chlor.	0.19	0.44	0.32	0.33
122	Lead	0.00	0.03	0.003	0.00
123	Mercury	0.004	1.58	0.56	0.56
124	Nickel	0.12	5.37	1.20	0.76
125	Selenium	0.00	3.76	1.48	1.27
126	Silver	0.00	0.73	0.17	0.01
128	Zinc	0.25	3.76	2.06	2.62
	Aluminum	0.00	0.05	0.01	0.00
	Ammonia	0.28	1.88	0.89	0.50
	Iron	NA	NA	NA	NA
	Manganese	0.04	15.3	2.65	0.72
	Phenols, Total	0.00	0.05	0.01	0.003
	Oil & Grease	1.73	18.3	10.2	8.86
	Total Suspended Solids	0.00	53.6	19.4	7.92
	pH, minimum	5.8	9.7	7.5	7.5
	pH, maximum	5.8	12.0	9.74	11.4

NA - Not Analyzed

Table V-102

POLLUTANT CONCENTRATIONS IN THE
ELECTROLYTE PREPARATION WASTE
STREAM
(Plant A)

	POLLUTANTS	mg/l
	Flow	
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	0.00
13	1,1 - Dichloroethane	0.00
29	1,1 - Dichloroethylene	0.00
30	1,2 - Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.00
115	Arsenic	4.47
118	Cadmium	0.00
119	Chromium, Total	0.00
	Chromium, Hexavalent	0.00
120	Copper	0.00
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
123	Mercury	0.04
124	Nickel	0.22
125	Selenium	3.60
126	Silver	0.79
128	Zinc	19.2
	Aluminum	0.00
	Ammonia	NA
	Iron	NA
	Manganese	0.00
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	70.0
	pH. minimum	12.8
	pH, Maximum	12.8

NA - Not Analyzed

Table V-103

POLLUTANT MASS LOADINGS IN THE ELECTROLYTE
PREPARATION WASTE STREAM   (Plant A)

	POLLUTANTS	mg/kg
	Flow (l/kg)	0.36
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	0.00
13	1,1 - Dichloroethane	0.00
29	1,1 - Dichloroethylene	0.00
30	1,2 - Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.00
115	Arsenic	1.63
118	Cadmium	0.00
119	Chromium, Total	0.00
	Chromium, Hexavalent	0.00
120	Copper	0.00
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.00
123	Mercury	0.02
124	Nickel	0.08
125	Selenium	1.31
126	Silver	0.29
128	Zinc	6.99
	Aluminum	0.00
	Ammonia	NA
	Iron	NA
	Manganese	0.00
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	25.5
	pH, minimum	12.8
	pH, maximum	12.8

NA - Not Analyzed

Table V-104

POLLUTANT CONCENTRATIONS IN THE SILVER
ETCH WASTE STREAM   (Plant A)

	POLLUTANTS	mg/l
	Temperature (Deg C)	10.0
11	1,1,1 - Trichloroethane	0.00
13	1,1 - Dichloroethane	0.00
29	1,1 - Dichloroethylene	0.00
30	1,2 - Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.00
115	Arsenic	0.00
118	Cadmium	0.04
119	Chromium, Total	0.01
	Chromium, Hexavalent	0.00
120	Copper	0.09
121	Cyanide, Total	0.01
	Cyanide, Amn. to Chlor.	0.00
122	Lead	0.05
123	Mercury	0.01
124	Nickel	0.00
125	Selenium	0.00
126	Silver	36.3
128	Zinc	1.06
	Aluminum	0.65
	Ammonia	2.00
	Iron	NA
	Manganese	0.01
	Phenols, Total	0.01
	Oil & Grease	1.00
	Total Suspended Solids	7.00
	pH, minimum	2.60
	pH, maximum	3.60

NA - Not Analyzed

Table V-105

POLLUTANT MASS LOADINGS IN THE SILVER
ETCH WASTE STREAM (Plant A)

	POLLUTANTS	mg/kg
	Flow (1/kg)	49.0
	Temperature (Deg C)	10.0
11	1,1,1 - Trichloroethane	0.01
13	1,1 - Dichloroethane	0.00
29	1,1 - Dichloroethylene	0.01
30	1,2 - Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.00
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.00
115	Arsenic	0.00
118	Cadmium	1.96
119	Chromium, Total	0.44
	Chromium, Hexavalent	0.00
120	Copper	4.32
121	Cyanide, Total	0.49
	Cyanide, Amn. to Chlor.	0.25
122	Lead	2.31
123	Mercury	0.44
124	Nickel	0.00
125	Selenium	0.00
126	Silver	1780.
128	Zinc	52.0
	Aluminum	31.9
	Ammonia	98.1
	Iron	NA
	Manganese	0.64
	Phenols, Total	0.54
	Oil & Grease	49.0
	Total Suspended Solids	343.
	pH, minimum	2.6
	pH, maximum	3.6

NA - Not Analyzed

Table V-106

POLLUTANT CONCENTRATIONS IN THE LAUNDRY
WASH AND EMPLOYEE SHOWER WASTE STREAMS
(Plant B)

	POLLUTANTS	mg/l DAYS		
		1	2	3
	Temperature (Deg C)	27.0	28.0	30.0
11	1,1,1 - Trichloroethane	*	*	*
13	1,1 - Dichloroethane	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	*	*	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	*	*	*
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	*	*	*
114	Antimony	NA	0.00	0.00
115	Arsenic	NA	0.00	0.00
118	Cadmium	NA	0.07	0.10
119	Chromium, Total	NA	0.00	0.00
	Chromium, Hexavalent	NA	0.00	0.00
120	Copper	NA	0.23	0.45
121	Cyanide, Total	0.03	0.01	0.00
	Cyanide, Amn. to Chlor.	I	I	I
122	Lead	NA	0.00	0.04
123	Mercury	NA	9.40	I
124	Nickel	NA	0.00	0.03
125	Selenium	NA	0.00	0.00
126	Silver	NA	1.46	0.43
128	Zinc	NA	0.82	1.22
	Aluminum	NA	0.16	0.16
	Ammonia	NA	NA	NA
	Iron	NA	NA	NA
	Manganese	NA	0.35	0.40
	Phenols, Total	0.19	0.05	0.08
	Oil & Grease	270.	5.20	14.0
	Total Suspended Solids	42.0	72.0	23.0
	pH, minimum	4.7	6.4	5.5
	pH, maximum	7.7	7.2	6.9

I - Interference
NA - Not Analyzed
* - Less than 0.01

Table V-107

POLLUTANT CONCENTRATIONS IN THE MANDATORY
EMPLOYEE WASH WASTE STREAM   (Plant A)

	POLLUTANTS	1	mg/l DAYS 2	3
	Temperature (Deg C)	17.0	29.0	26.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethylene	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.00	0.00	0.00
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.00
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.03	0.01	0.02
121	Cyanide, Total	0.01	0.00	0.00
	Cyanide, Amn. to Chlor.	0.01	0.00	0.00
122	Lead	0.00	0.00	0.00
123	Mercury	0.00	0.00	0.00
124	Nickel	0.00	0.00	0.00
125	Selenium	NA	NA	NA
126	Silver	0.00	0.00	0.00
128	Zinc	0.10	0.15	0.15
	Aluminum	NA	NA	NA
	Ammonia	6.23	0.73	0.13
	Iron	NA	NA	NA
	Manganese	0.23	0.10	0.36
	Phenols, Total	0.22	0.04	I
	Oil & Grease	8.30	2.00	42.0
	Total Suspended Solids	133.	84.0	55.0
	pH, minimum	NA	NA	NA
	pH, maximum	NA	NA	NA

I - Interference
NA - Not Analyzed

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Table V-108

POLLUTANT MASS LOADINGS IN THE MANDATORY
EMPLOYEE WASH WASTE STREAMS

(Plant A)

	POLLUTANTS	1	mg/kg DAYS 2	3
	Flow (1/kg)	0.27	0.27	0.27
	Temperature (Deg C)	17.0	29.0	26.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethylene	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.00	0.00	0.00
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.00
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	0.01	0.04	0.01
121	Cyanide, Total	0.00	0.00	0.00
	Cyanide, Amn. to Chlor.	0.001	0.00	0.00
122	Lead	0.01	0.00	0.00
123	Mercury	0.00	0.00	0.00
124	Nickel	0.00	0.00	0.00
125	Selenium	NA	NA	NA
126	Silver	0.00	0.00	0.00
128	Zinc	0.03	0.04	0.04
	Aluminum	NA	NA	NA
	Ammonia	1.66	0.19	0.04
	Iron	NA	NA	NA
	Manganese	0.06	0.03	0.10
	Phenols, Total	0.01	0.01	I
	Oil & Grease	2.21	0.53	11.2
	Total Suspended Solids	35.5	22.3	14.6
	pH, minimum	NA	NA	NA
	pH, maximum	NA	NA	NA

I - Interference
NA - Not Analyzed

Table V-109

POLLUTANT CONCENTRATIONS IN THE REJECT
CELL HANDLING (Plant A)

	POLLUTANTS	mg/l
	Flow	0.03 1/kg
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	NA
13	1,1 - Dichloroethane	NA
29	1,1 - Dichloroethylene	NA
30	1,2 - Trans-dichloroethylene	NA
38	Ethylbenzene	NA
44	Methylene chloride	NA
55	Naphthalene	NA
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	NA
85	Tetrachloroethylene	NA
86	Toluene	NA
87	Trichloroethylene	NA
114	Antimony	NA
115	Arsenic	NA
118	Cadmium	0.02
119	Chromium, Total	0.10
	Chromium, Hexavalent	NA
120	Copper	5.46
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.34
123	Mercury	17.0
124	Nickel	0.57
125	Selenium	NA
126	Silver	3.59
128	Zinc	156.
	Aluminum	106.
	Ammonia	NA
	Iron	0.57
	Manganese	0.18
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	NA
	pH, minimum	NA
	pH, maximum	NA

NA - Not Analyzed

Table V-110

POLLUTANT CONCENTRATIONS IN THE
REJECT CELL HANDLING WASTE STREAMS

(Plant B)

	POLLUTANTS	1	mg/l DAYS 2	3
	Temperature (Deg C)	18.0	19.0	18.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethylene	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.04	0.08	0.01
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.10	0.19	0.15
118	Cadmium	0.00	0.00	0.00
119	Chromium, Total	0.00	0.02	0.01
	Chromium, Hexavalent	0.00	I	0.00
120	Copper	0.08	0.30	0.32
121	Cyanide, Total	0.10	0.01	0.07
	Cyanide, Amn. to Chlor.	0.01	0.01	0.00
122	Lead	0.06	0.00	0.00
123	Mercury	0.47	1.00	0.37
124	Nickel	0.01	0.07	0.18
125	Selenium	NA	NA	NA
126	Silver	0.00	0.00	0.00
128	Zinc	730.	495.	206.
	Aluminum	NA	NA	NA
	Ammonia	5.57	8.89	1.37
	Iron	NA	NA	NA
	Manganese	0.02	0.15	0.29
	Phenols, Total	0.00	0.00	0.12
	Oil & Grease	13.3	6.00	19.0
	Total Suspended Solids	762.	500.	1310.
	pH, minimum	NA	NA	NA
	pH, maximum	NA	NA	NA

I - Interference
NA - Not Analyzed

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Table V-111

POLLUTANT MASS LOADINGS IN THE
REJECT CELL HANDLING WASTE STREAMS

(Plant B)

| POLLUTANTS | | mg/kg DAYS | | |
		1	2	3
	Flow (l/kg)	0.003	0.002	0.003
	Temperature (Deg C)	18.0	19.0	18.0
11	1,1,1 - Trichloroethane	0.00	0.00	0.00
13	1,1 - Dichloroethane	NA	NA	NA
29	1,1 - Dichloroethylene	NA	NA	NA
30	1,2 - Trans-dichloroethylene	NA	NA	NA
38	Ethylbenzene	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	NA	NA	NA
64	Pentachlorophenol	0.00	0.00	0.00
66	Bis(2-ethylhexyl) phthalate	0.00	0.00	0.00
70	Diethyl phthalate	NA	NA	NA
85	Tetrachloroethylene	NA	NA	NA
86	Toluene	NA	NA	NA
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.00	0.00
119	Chromium, Total	0.00	0.00	0.00
	Chromium, Hexavalent	0.00	I	0.00
120	Copper	0.00	0.001	0.001
121	Cyanide, Total	0.00	0.00	0.00
	Cyanide, Amn. to Chlor.	0.00	0.00	0.00
122	Lead	0.00	0.00	0.00
123	Mercury	0.001	0.002	0.001
124	Nickel	0.00	0.00	0.00
125	Selenium	NA	NA	NA
126	Silver	0.00	0.00	0.00
128	Zinc	2.00	0.90	0.56
	Aluminum	NA	NA	NA
	Ammonia	0.02	0.02	0.004
	Iron	NA	NA	NA
	Manganese	0.00	0.00	0.001
	Phenols, Total	0.00	0.00	0.00
	Oil & Grease	0.04	0.01	0.05
	Total Suspended Solids	2.08	0.91	3.58
	pH, minimum	NA	NA	NA
	pH, maximum	NA	NA	NA

I - Interference
NA - Not Analyzed

Table V-112

POLLUTANT CONCENTRATIONS IN THE FLOOR WASH WASTE STREAM

(Plant A)

mg/l

POLLUTANTS

	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	NA
13	1,1 - Dichloroethane	NA
29	1,1 - Dichloroethylene	NA
30	1,2 - Trans-dichloroethylene	NA
38	Ethylbenzene	NA
44	Methylene chloride	NA
55	Naphthalene	NA
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	NA
85	Tetrachloroethylene	NA
86	Toluene	NA
87	Trichloroethylene	NA
114	Antimony	0.00
115	Arsenic	0.00
118	Cadmium	0.04
119	Chromium, Total	0.35
	Chromium, Hexavalent	0.00
120	Copper	0.23
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	4.13
123	Mercury	I
124	Nickel	0.38
125	Selenium	0.00
126	Silver	49.5
128	Zinc	600.
	Aluminum	5.83
	Ammonia	120.
	Iron	NA
	Manganese	0.34
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	2800.
	pH, minimum	NA
	pH, maximum	NA

I - Interference
NA - Not Analyzed

Table V-113

POLLUTANT MASS LOADINGS IN THE FLOOR WASH WASTE STREAM

(Plant A)

mg/kg

POLLUTANTS

		mg/kg
	Flow (1/kg)	0.30
	Temperature (Deg C)	NA
11	1,1,1 - Trichloroethane	NA
13	1,1 - Dichloroethane	NA
29	1,1 - Dichloroethylene	NA
30	1,2 - Trans-dichloroethylene	NA
38	Ethylbenzene	NA
44	Methylene chloride	NA
55	Naphthalene	NA
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	NA
85	Tetrachloroethylene	NA
86	Toluene	NA
87	Trichloroethylene	NA
114	Antimony	0.00
115	Arsenic	0.00
118	Cadmium	0.01
119	Chromium, Total	0.10
	Chromium, Hexavalent	0.00
120	Copper	0.07
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	1.22
123	Mercury	I
124	Nickel	0.11
125	Selenium	0.00
126	Silver	14.6
128	Zinc	177.
	Aluminum	1.72
	Ammonia	35.5
	Iron	NA
	Manganese	0.10
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	828.
	pH, minimum	NA
	pH, maximum	NA

I - Interference
NA - Not Analyzed

Table V-114

POLLUTANT CONCENTRATIONS IN THE EQUIPMENT WASH WASTE STREAMS

	POLLUTANTS	PLANT B	mg/l DAYS		PLANT A
		1	2	3	
	Temperature (Deg C)	18.8	10.0	50.0	NA
11	1,1,1 - Trichloroethane	0.00	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	*
44	Methylene chloride	0.00	0.00	0.00	*
55	Naphthalene	0.00	0.00	0.00	*
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	*
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	*	*	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.01	0.10	0.09	0.00
118	Cadmium	0.19	0.02	0.02	0.02
119	Chromium, Total	0.00	0.00	0.01	0.01
	Chromium, Hexavalent	0.00	I	0.00	0.00
120	Copper	0.01	NA	0.03	0.04
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.01	NA	0.00	0.00
123	Mercury	0.12	0.40	0.04	0.22
124	Nickel	0.13	0.02	0.04	0.10
125	Selenium	0.00	0.05	0.07	0.00
126	Silver	0.03	0.00	0.35	0.96
128	Zinc	8.03	0.66	1.40	1.79
	Aluminum	0.12	NA	0.00	0.00
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.02	0.00	0.02	0.07
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	51.5	112.	68.0	98.0
	pH, minimum	12.0	11.8	12.0	5.6
	pH, maximum	12.2	11.8	12.2	6.5

I - Interference
NA - Not Analyzed
* - Less than 0.01

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Table V-115

POLLUTANT MASS LOADINGS IN THE EQUIPMENT WASH WASTE STREAMS

	POLLUTANTS	Plant B 1	mg/kg DAYS 2	3	Plant A
	Flow (1/kg)	16.6	6.79	3.47	5.09
	Temperature (Deg C)	18.8	10.0	50.0	NA
11	1,1,1 - Trichloroethane	0.00	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.10	0.68	0.31	0.00
118	Cadmium	3.13	0.10	0.07	0.12
119	Chromium, Total	0.00	0.00	0.04	0.06
	Chromium, Hexavalent	0.00	I	0.00	0.00
120	Copper	0.08	NA	0.09	0.21
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA
122	Lead	0.08	NA	0.00	0.00
123	Mercury	1.98	2.72	0.13	1.12
124	Nickel	2.13	0.14	0.13	0.51
125	Selenium	0.00	0.34	0.24	0.00
126	Silver	0.57	0.00	1.21	4.89
128	Zinc	134.	4.48	4.86	9.11
	Aluminum	2.06	NA	0.00	0.00
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.34	0.00	0.07	0.37
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	856.	761.	236.	499.
	pH, minimum	12.0	11.8	12.0	5.6
	pH, maximum	12.2	11.8	12.2	6.5

I - Interference
NA - Not Analyzed

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Table V-116

STATISTICAL ANALYSIS (mg/l) OF THE EQUIPMENT WASH WASTE STREAMS

POLLUTANTS		MINIMUM	MAXIMUM	MEAN	MEDIAN	# VAL	# ZEROS	# PTS
	Temperature (Deg C)	10.0	50.0	19.3	18.8	3	0	3
11	1,1,1 - Trichloroethane	0.00	*	*	0.00	1	3	4
13	1,1 - Dichloroethane	0.00	*	*	0.00	1	3	4
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00	0	4	4
38	Ethylbenzene	0.00	*	*	0.00	1	3	4
44	Methylene chloride	0.00	*	*	0.00	1	3	4
55	Naphthalene	0.00	*	*	0.00	1	3	4
64	Pentachlorophenol	NA	NA	NA	NA			
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA			
70	Diethyl phthalate	0.00	*	*	*	3	1	4
85	Tetrachloroethylene	0.00	0.00	0.00	0.00	0	4	4
86	Toluene	0.00	*	*	*	3	1	4
87	Trichloroethylene	0.00	0.00	0.00	0.00	0	4	4
114	Antimony	0.00	0.00	0.00	0.00	0	4	4
115	Arsenic	0.00	0.10	0.05	0.05	3	1	4
118	Cadmium	0.02	0.19	0.06	0.02	4	0	4
119	Chromium, Total	0.00	0.01	0.01	0.01	2	2	4
	Chromium, Hexavalent	0.00	0.00	0.00	0.00	0	3	3
120	Copper	0.01	0.04	0.02	0.03	3	0	3
121	Cyanide, Total	NA	NA	NA	NA			
	Cyanide, Amn. to Chlor.	NA	NA	NA	NA			
122	Lead	0.00	0.01	*	0.00	1	2	3
123	Mercury	0.04	0.40	0.19	0.17	4	0	4
124	Nickel	0.02	0.13	0.07	0.07	4	0	4
125	Selenium	0.00	0.07	0.03	0.03	2	2	4
126	Silver	0.00	0.96	0.34	0.19	3	1	4
128	Zinc	0.66	8.03	2.97	1.60	4	0	4
	Aluminum	0.00	0.12	0.04	0.00	1	2	3
	Ammonia	NA	NA	NA	NA			
	Iron	NA	NA	NA	NA			
	Manganese	0.00	0.07	0.03	0.02	3	1	4
	Phenols, Total	NA	NA	NA	NA			
	Oil & Grease	NA	NA	NA	NA			
	Total Suspended Solids	51.4	112.	82.4	83.0	4	0	4
	pH, minimum	5.6	12.0	10.3	11.9	4	0	4
	pH, maximum	6.5	12.2	10.7	12.0	4	0	4

NA - Not Analyzed
* - Less than 0.01
Number of values may include concentrations less than 0.005
shown as 0.00 on tables.

Table V-117

STATISTICAL ANALYSIS (mg/kg) OF THE EQUIPMENT WASH WASTE STREAMS

POLLUTANTS

		MINIMUM	MAXIMUM	MEAN	MEDIAN
	Flow (1/kg)	3.47	16.6	8.00	5.94
	Temperature (Deg C)	10.0	50.0	19.3	18.8
11	1,1,1 - Trichloroethane	0.00	0.00	0.00	0.00
13	1,1 - Dichloroethane	0.00	0.00	0.00	0.00
29	1,1 - Dichloroethylene	0.00	0.00	0.00	0.00
30	1,2 - Trans-dichloroethylene	0.00	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00	0.00
115	Arsenic	0.00	0.68	0.27	0.21
118	Cadmium	0.07	3.13	0.86	0.11
119	Chromium, Total	0.00	0.06	0.02	0.02
	Chromium, Hexavalent	0.00	0.00	0.00	0.00
120	Copper	0.08	0.21	0.13	0.09
121	Cyanide, Total	NA	NA	NA	NA
	Cyanide, Am. to Chlor.	NA	NA	NA	NA
122	Lead	0.00	0.08	0.03	0.00
123	Mercury	0.13	2.72	1.49	1.55
124	Nickel	0.13	2.13	0.73	0.32
125	Selenium	0.00	0.34	0.15	0.12
126	Silver	0.00	4.89	1.67	0.89
128	Zinc	4.48	134.	38.0	6.98
	Aluminum	0.00	2.06	0.69	0.00
	Ammonia	NA	NA	NA	NA
	Iron	NA	NA	NA	NA
	Manganese	0.00	0.37	0.19	0.20
	Phenols, Total	NA	NA	NA	NA
	Oil & Grease	NA	NA	NA	NA
	Total Suspended Solids	236.	856.	588.	630.
	pH, minimum	5.6	12.0	10.4	11.9
	pH, maximum	6.5	12.2	10.7	12.0

NA - Not Analyzed

Table V-118

POLLUTANT CONCENTRATIONS IN THE SILVER
POWDER PRODUCTION ELEMENT WASTE STREAMS
(Plant A)

		mg/l		
	POLLUTANTS		DAYS	
		1	2	3
	Temperature (Deg C)	14.0	15.0	14.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00
13	1,1-Dichloroethane	0.00	0.00	0.00
29	1,1-Dichloroethylene	0.00	0.00	0.00
30	1,2-Trans-dichloroethylene	0.00	0.00	0.00
38	Ethylbenzene	0.00	0.00	0.00
44	Methylene chloride	0.00	0.00	0.00
55	Naphthalene	0.00	0.00	0.00
64	Pentachlorophenol	NA	NA	NA
66	Bis(2-ethylhexyl) phthalate	NA	NA	NA
70	Diethyl phthalate	0.00	0.00	0.00
85	Tetrachloroethylene	0.00	0.00	0.00
86	Toluene	0.00	0.00	0.00
87	Trichloroethylene	0.00	0.00	0.00
114	Antimony	0.00	0.00	0.00
115	Arsenic	0.00	0.00	0.00
118	Cadmium	0.00	0.01	0.00
119	Chromium, Total	0.70	1.52	0.58
	Chromium, Hexavalent	0.00	0.00	0.00
120	Copper	4.35	10.5	4.37
121	Cyanide, Total	NA	NA	NA
	Cyanide, Amn. to Chlor.	NA	NA	NA
122	Lead	0.16	0.28	0.00
123	Mercury	0.01	0.00	0.00
124	Nickel	0.61	1.45	0.57
125	Selenium	0.00	0.00	0.0
126	Silver	12.0	24.1	13.9
128	Zinc	0.18	0.44	0.38
	Aluminum	3.40	12.0	0.48
	Ammonia	NA	NA	NA
	Iron	NA	NA	NA
	Manganese	0.11	0.08	0.10
	Phenols, Total	NA	NA	NA
	Oil & Grease	NA	NA	NA
	Total Suspended Solids	27.0	23.0	13.0
	pH, Minimum	2.0	2.2	2.1
	pH, Maximum	2.6	2.5	2.5

NA-Not Analyzed

Table V-119

POLLUTANT MASS LOADINGS IN THE
SILVER POWDER PRODUCTION
WASTE STREAMS (PLANT A)

mg/kg

POLLUTANTS		DAYS	
	1	2	3
Flow (1/kg)	23.7	20.1	19.8
Temperature (Deg C)	14.0	15.0	14.0
11 1,1,1-Trichloroethane	0.00	0.00	0.00
13 1,1-Dichloroethane	0.00	0.00	0.00
29 1,1-Dichloroethylene	0.00	0.00	0.00
30 1,2-Trans-dichloroethylene	0.00	0.00	0.00
38 Ethylbenzene	0.00	0.00	0.00
44 Methylene chloride	0.002	0.002	0.002
55 Naphthalene	0.00	0.00	0.00
64 Pentachlorophenol	NA	NA	NA
66 Bis(2-ethylhexyl) phthalate	NA	NA	NA
70 Diethyl phthalate	0.00	0.00	0.00
85 Tetrachloroethylene	0.00	0.00	0.00
86 Toluene	0.00	0.00	0.00
87 Trichloroethylene	0.00	0.00	0.00
114 Antimony	0.00	0.00	0.00
115 Arsenic	0.00	0.00	0.00
118 Cadmium	0.00	0.14	0.00
119 Chromium, Total	16.6	30.6	11.5
Chromium, Hexavalent	0.00	0.00	0.00
120 Copper	103.	212.	86.6
121 Cyanide, Total	NA	NA	NA
Cyanide, Amn. to Chlor.	NA	NA	NA
122 Lead	3.80	5.64	0.00
123 Mercury	0.19	0.00	0.00
124 Nickel	14.5	29.2	11.3
125 Selenium	0.00	0.00	0.00
126 Silver	285.	485.	275.
128 Zinc	4.27	8.86	7.53
Aluminum	80.7	242.	9.51
Ammonia	NA	NA	NA
Iron	NA	NA	NA
Manganese	2.61	1.57	1.98
Phenols, Total	NA	NA	NA
Oil & Grease	NA	NA	NA
Total Suspended Solids	641.	463.	258.
pH, Minimum	2.0	2.2	2.1
pH, Maximum	2.6	2.5	2.5

NA-Not Analyzed

Table V-120

POLLUTANT CONCENTRATIONS IN THE WASTE
STREAMS FROM SILVER PEROXIDE PRODUCTION
ELEMENT

mg/l

POLLUTANTS

		mg/l
	Temperature (Deg C)	NA
11	1,1,1-Trichloroethane	*
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	*
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.00
115	Arsenic	5.91
118	Cadmium	0.00
119	Chromium, Total	0.09
	Chromium, Hexavalent	I
120	Copper	0.00
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.00
123	Mercury	0.04
124	Nickel	0.00
125	Selenium	4.80
126	Silver	0.77
128	Zinc	0.08
	Aluminum	0.00
	Ammonia	NA
	Iron	NA
	Manganese	0.00
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	31.0
	pH, Minimum	11.0
	pH, Maximum	12.5

I-Interference
NA-Not Analyzed
*-Less than 0.01

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Table V-121

POLLUTANT MASS LOADINGS IN THE WASTE
STREAMS FROM SILVER PEROXIDE PRODUCTION
ELEMENT

mg/kg

POLLUTANTS

	FLOW (l/kg)	14.3
	Temperature (Deg C)	
11	1,1,1-Trichloroethane	*
13	1,1-Dichloroethane	0.00
29	1,1-Dichloroethylene	0.00
30	1,2-Trans-dichloroethylene	0.00
38	Ethylbenzene	0.00
44	Methylene chloride	0.04
55	Naphthalene	0.00
64	Pentachlorophenol	NA
66	Bis(2-ethylhexyl) phthalate	NA
70	Diethyl phthalate	0.00
85	Tetrachloroethylene	0.00
86	Toluene	0.00
87	Trichloroethylene	0.00
114	Antimony	0.00
115	Arsenic	84.4
118	Cadmium	0.00
119	Chromium, Total	1.29
	Chromium, Hexavalent	I
120	Copper	0.00
121	Cyanide, Total	NA
	Cyanide, Amn. to Chlor.	NA
122	Lead	0.00
123	Mercury	0.53
124	Nickel	0.00
125	Selenium	68.5
126	Silver	11.0
128	Zinc	1.07
	Aluminum	0.00
	Ammonia	NA
	Iron	NA
	Manganese	0.00
	Phenols, Total	NA
	Oil & Grease	NA
	Total Suspended Solids	443
	pH, Minimum	11.0
	pH, Maximum	12.5

I-Interference
NA-Not Analyzed
*-Less than 0.01

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

The priority, non-conventional, and conventional pollutant parameters
that are to be examined for possible regulation were presented in
Section V. Data from plant sampling visits, and results of subsequent
chemical analysis were presented and discussed. Pollutant parameters
were selected for verification according to a specified rationale.

Each of the pollutant parameters selected for verification analysis is
discussed in detail. The selected priority pollutants are presented
in numerical order and are followed by non-conventional pollutants and
then conventional pollutants, both in alphabetical order. The final
part of this section sets forth the pollutants which are to be
considered for regulation in each subcategory. The rationale for that
final selection is included.

VERIFICATION PARAMETERS

Pollutant parameters selected for verification sampling and analysis
are listed in Table V-8 (Page 262) and the subcategory for each is
designated. The subsequent discussion is designed to provide
information about: where the pollutant comes from - whether it is a
naturally occurring element, processed metal, or manufactured
compound; general physical properties and the physical form of the
pollutant; toxic effects of the pollutant in humans and other animals;
and behavior of the pollutant in POTW at the concentrations that might
be expected from industrial dischargers.

1,1,1-Trichloroethane(11). 1,1,1-Trichloroethane is one of the two
possible trichlorethanes. It is manufactured by hydrochlorinating
vinyl chloride to 1,1-dichloroethane which is then chlorinated to the
desired product. 1,1,1-Trichloroethane is a liquid at room
temperature with a vapor pressure of 96 mm Hg at 20°C and a boiling
point of 74°C. Its formula is CCl_3CH_3. It is slightly soluble in
water (0.48 g/l) and is very soluble in organic solvents. U.S.
annual production is greater than one-third of a million tons. 1,1,1-
Trichloroethane is used as an industrial solvent and degreasing agent.

Most human toxicity data for 1,1,1-trichloroethane relates to
inhalation and dermal exposure routes. Limited data are available for
determining toxicity of ingested 1,1,1-trichloroethane, and those data
are all for the compound itself not solutions in water. No data are
available regarding its toxicity to fish and aquatic organisms. For
the protection of human health from the toxic properties of 1,1,1-
trichloroethane ingested through the consumption of water and fish,

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the ambient water criterion is 15.7 mg/l. The criterion is based on bioassy for possible carcinogenicity.

No detailed study of 1,1,1-trichloroethane behavior in POTW is available. However, it has been demonstrated that none of the organic priority pollutants of this type can be broken down by biological treatment processes as readily as fatty acids, carbohydrates, or proteins.

Biochemical oxidation of many of the organic priority pollutants has been investigated, at least in laboratory scale studies, at concentrations higher than commonly expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces a moderate degree of degradation of 1,1,1-trichloroethane. No evidence is available for drawing conclusions about its possible toxic or inhibitory effect on POTW operation. However, for degradation to occur a fairly constant input of the compound would be necessary.

Its water solubility would allow 1,1,1-trichloroethane, present in the influent and not biodegradable, to pass through a POTW into the effluent. One factor which has received some attention, but no detailed study, is the volatilization of the lower molecular weight organics from POTW. If 1,1,1-trichloroethane is not biodegraded, it will volatilize during aeration processes in the POTW.

1,1-Dichloroethane(13). 1,1-Dichloroethane, also called ethylidene dichloride and ethylidene chloride is a colorless liquid manufactured by reacting hydrogen chloride with vinyl chloride in 1,1-dichloro-ethane solution in the presence of a catalyst. However, it is reportedly not manufactured commercially in the U.S. 1,1-dichloroethane boils at 57°C and has a vapor pressure of 182 mm Hg at 20°C. It is slightly soluble in water (5.5 g/l at 20°C) and very soluble in organic solvents.

1,1-Dichloroethane is used as an extractant for heat-sensitive substances and as a solvent for rubber and silicone grease.

1,1-Dichloroethane is less toxic than its isomer (1,2-dichloroethane) but its use as an anesthetic has been discontinued because of marked excitation of the heart. It causes central nervous system depression in humans. There are insufficient data to derive water quality criteria for 1,1-dichloroethane.

Data on the behavior of 1,1-dichloroethane in POTW are not available. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those

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expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusion reached by study of the limted data is that biological treatment produces only a moderate removal of 1,1-dichloroethane in POTW by degradation.

The high vapor pressure of 1,1-dichloroethane is expected to result in volatilization of some of the compound from aerobic processes in POTW. Its water solubility will result in some of the 1,1-dichloroethane which enters the POTW leaving in the effluent from the POTW.

Chloroform(23). Chloroform is a colorless liquid manufactured commercially by chlorination of methane. Careful control of conditions maximizes chloroform production, but other products must be separated. Chloroform boils at 61°C and has a vapor pressure of 200 mm Hg at 25°C. It is slightly soluble in water (8.22 g/l at 20°C) and readily soluble in organic solvents.

Chloroform is used as a solvent and to manufacture refrigerents, pharmaceuticals, plastics, and anesthetics. It is seldom used as an anesthetic.

Toxic effects of chloroform on humans include central nervous system depression, gastrointestinal irritation, liver and kidney damage and possible cardiac sensitization to adrenalin. Carcinogenicity has been demonstrated for chloroform on laboratory animals.

For the maximum protection of human health from the potential carcinogenic effects of exposure to chloroform through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of chloroform estimated to result in additional lifetime cancer risks at the levels of 10^{-7}, 10^{-6}, and 10^{-5} were 0.000021 mg/l, 0.00021 mg/l, and 0.0021 mg/l, respectively.

No data are available regarding the behavior of chloroform in a POTW. However, the biochemical oxidation of this compound was studied in one laboratory scale study at concentrations higher than these expected to be contained by most municipal wastewaters. After 5, 10, and 20 days no degradation of chloroform was observed. The conclusion reached is that biological treatment produces little or no removal by degradation of chloroform in POTW.

The high vapor pressure of chloroform is expected to result in volatilization of the compound from aerobic treatment steps in POTW. Remaining chloroform is expected to pass through into the POTW effluent.

1,1-Dichloroethylene(29). 1,1-Dichloroethylene (1,1-DCE), also called vinylidene chloride, is a clear colorless liquid manufactured by dehydrochlorination of 1,1,2-trichloroethane. 1,1-DCE has the formula CCl_2CH_2. It has a boiling point of 32°C, and a vapor pressure of 591 mm Hg at 25°C. 1,1-DCE is slightly soluble in water (2.5 mg/l) and is soluble in many organic solvents. U.S. production is in the range of a hundreds of thousands of tons annually.

1,1-DCE is used as a chemical intermediate and for copolymer coatings or films. It may enter the wastewater of an industrial facility as the result of decomposition of 1,1,1-trichloroethylene used in degreasing operations, or by migration from vinylidene chloride copolymers exposed to the process water.

Human toxicity of 1,1-DCE has not been demonstrated, however it is a suspected human carcinogen. Mammalian toxicity studies have focused on the liver and kidney damage produced by 1,1-DCE. Various changes occur in those organs in rats and mice ingesting 1,1-DCE.

For the maximum protection of human health from the potential carcinogenic effects of exposure to 1,1-dichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. The concentration of 1,1-DCE estimated to result in an additional lifetime cancer risk of 1 in 100,000 is 0.0013 mg/l.

Under laboratory conditions, dichloroethylenes have been shown to be toxic to fish. The primary effect of acute toxicity of the dichloroethylenes is depression of the central nervous system. The octanol/water partition coefficient of 1,1-DCE indicates it should not accumulate significantly in animals.

The behavior of 1,1-DCE in POTW has not been studied. However, its very high vapor pressure is expected to result in release of significant percentages of this material to the atmosphere in any treatment involving aeration. Degradation of dichloroethylene in air is reported to occur, with a half-life of 8 weeks.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces little or no degradation of 1,1-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,1-DCE on POTW operation. Because of water solubility, 1,1-DCE which is not volatilized or degraded is expected to pass through POTW. Very little 1,1-DCE is expected to be found in sludge from POTW.

1,2-trans-Dichloroethylene(30). 1,1-trans-Dichloroethylene (trans-1,2-DCE) is a clear, colorless liquid with the formula CHClCHCl. Trans-1,2-DCE is produced in mixture with the cis-isomer by chlorination of acetylene. The cis-isomer has distinctly different physical properties. Industrially, the mixture is used rather than the separate isomers. Trans-1,2-DCE has a boiling point of 48°C, and a vapor pressure of 324 mm Hg at 25°C.

The principal use of 1,2-dichloroethylene (mixed isomers) is to produce vinyl chloride. It is used as a lead scavenger in gasoline, general solvent, and for synthesis of various other organic chemicals. When it is used as a solvent trans-1,2-DCE can enter wastewater streams.

Although trans-1,2-DCE is thought to produce fatty degeneration of mammalian liver, there are insufficient data on which to base any ambient water criterion.

In the one reported toxicity test of trans-1,2-DCE on aquatic life, the compound appeared to be about half as toxic as the other dichloroethylene (1,1-DCE) on the priority pollutants list.

The behavior of trans-1,2-DCE in POTW has not been studied. However, its high vapor pressure is expected to result in release of significant percentage of this compound to the atmosphere in any treatment involving aeration. Degradation of the dichloroethylenes in air is reported to occur, with a half-life of 8 weeks.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by the study of the limited data is that biochemical oxidation produces little or no degradation of 1,2-trans-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,2-trans-dichloroethylene on POTW operation. It is expected that its low molecular weight and degree of water solubility will result in trans-1,2-DCE passing through a POTW to the effluent if it is not degraded or volatilized. Very little trans-1,2-DCE is expected to be found in sludge from POTW.

Ethylbenzene(38). Ethylbenzene is a colorless, flammable liquid manufactured commercially from benzene and ethylene. Approximately half of the benzene used in the U.S. goes into the manufacture of more than three million tons of ethylbenzene annually. Ethylbenzene boils at 136°C and has a vapor pressure of 7 mm Hg at 20°C. It is slightly soluble in water (0.14 g/l at 15°C) and is very soluble in organic solvents.

About 98 percent of the ethylbenzene produced in the U.S. goes into the production of styrene, much of which is used in the plastics and synthetic rubber industries. Ethylbenzene is a consitutent of xylene mixtures used as diluents in the paint industry, agricultural insecticide sprays, and gasoline blends.

Although humans are exposed to ethylbenzene from a variety of sources in the environment, little information on effects of ethylbenzene in man or animals is available. Inhalation can irritate eyes, affect the respiratory tract, or cause vertigo. In laboratory animals ethylbenzene exhibited low toxicity. There are no data available on teratogenicity, mutagenicity, or carcinogenicity of ethylbenzene.

Criteria are based on data derived from inhalation exposure limits. For the protection of human health from the toxic properties of ethylbenzene ingested through water and contaminated aquatic organisms, the ambient water quality criterion is 1.1 mg/l.

The behavior of ethylbenzene in POTW has not been studied in detail. Laboratory scale studies of the biochemical oxidation of ethylbenzene at concentrations greater than would normally be found in municipal wastewaters have demonstrated varying degrees of degradation. In one study with phenol-acclimated seed cultures 27 percent degradation was observed in a half day at 250 mg/l ethylbezene. Another study at unspecified conditions showed 32, 38, and 45 percent degradation after 5, 10, and 20 days, respectively. Based on these results and general observations relating molecular structure to ease of degradation, the conclusion is reached that biological treatment produces only a moderate removal of ethylbenzene in POTW by degradation.

Other studies suggest that most of the ethylbenzene entering a POTW is removed from the aqueous stream to the sludge. The ethylbenzene contained in the sludge removed from the POTW may volatilize.

Methylene Chloride(44). Methylene chloride, also called dichloromethane (CH_2Cl_2), is a colorless liquid manufactured by chlorination of methane or methyl chloride followed by separation from the higher chlorinated methanes formed as coproducts. Methylene chloride boils at 40°C, and has a vapor pressure of 362 mm Hg at 20°C. It is slightly soluble in water (20 g/l at 20°C), and very soluble in organic solvents. U.S. annual production is about 250,000 tons.

Methylene chloride is a common industrial solvent found in insecticides, metal cleaners, paint, and paint and varnish removers.

Methylene chloride is not generally regarded as highly toxic to humans. Most human toxicity data are for exposure by inhalation. Inhaled methylene chloride acts as a central nervous system

depressant. There is also evidence that the compound causes heart failure when large amounts are inhaled.

Methylene chloride does produce mutation in tests for this effect. In addition a bioassay recognized for its extermely high sensitivity to strong and weak carcinogens produced results which were marginally significant. Thus potential carcinogenic effects of methylene chloride are not confirmed or denied, but are under continuous study. Difficulty in conduting and interpreting the test results from the low boiling point (40°C) of methylene chloride which increases the difficulty of maintaining the compound in growth media during incubation at 37°C; and from the difficulty of removing all impurities, some of which might themselves be carcinogenic.

For the protection of human health from the toxic properties of methylene chloride ingested through water and contaminated aquatic organisms, the ambient water criterion is 0.002 mg/l.

The behavior of methylene chloride in POTW has not been studied in any detail. However, the biochemical oxidation of this compound was studied in one laboratory scale study at concentrations higher than those expected to be contained by most municipal wastewaters. After five days no degradation of methylene chloride was observed. The conclusion reached is that biological treatment produces litte or no removal by degradation of methylene chloride in POTW.

The high vapor pressure of methylene chloride is expected to result in volatilization of the compound from aerobic treatment steps in POTW. It has been reported that methylene chloride inhibits anaerobic processes in POTW. Methylene chloride that is not volatilized in the POTW is expected to pass through into the effluent.

Naphthalene(55). Naphthalene is an aromatic hydrocarbon with two orthocondensed benzene rings and a molecular formula of $C_{10}H_8$. As such it is properly classed as a polynuclear aromatic hydrocarbon (PAH). Pure naphthalene is a white crystalline solid melting at 80°C. For a solid, it has a relatively high vapor pressure (0.05 mm Hg at 20°C), and moderate water solubility (19 mg/l at 20°C). Naphthalene is the most abundant single component of coal tar. Production is more than a third of a million tons annually in the U.S. About three fourths of the production is used as feedstock for phthalic anhydride manufacture. Most of the remaining production goes into manufacture of insecticide, dyestuffs, pigments, and pharmaceuticals. Chlorinated and partially hydrogenated naphthalenes are used in some solvent mixtures. Naphthalene is also used as a moth repellent.

Napthalene, ingested by humans, has reportedly caused vision loss (cataracts), hemolytic anemia, and occasionally, renal disease. These effects of naphthalene ingestion are confirmed by studies on

laboratory animals. No carcinogenicity studies are available which can be used to demonstrate carcinogenic activity for naphthalene. Naphthalene does bioconcentrate in aquatic organisms.

For the protection of human health from the toxic properties of naphthalene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be .143 mg/l.

Only a limited number of studies have been conducted to determine the effects of naphthalene on aquatic organisms. The data from those studies show only moderate toxicity.

Naphthalene has been detected in sewage plant effluents at concentrations up to .022 mg/l in studies carried out by the U.S. EPA. Influent levels were not reported. The behavior of naphthalene in POTW has not been studied. However, recent studies have determined that naphthalene will accumulate in sediments at 100 times the concentration in overlying water. These results suggest that naphthalene will be readily removed by primary and secondary settling in POTW, if it is not biologically degraded.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces a high removal by degradation of naphthalene. One recent study has shown that microorganisms can degrade naphthalene, first to a dihydro compound, and ultimately to carbon dioxide and water.

Pentachlorophenol(64). Pentachlorophenol (C_6Cl_5OH) is a white crystalline solid produced commercially by chlorination of phenol or polychlorophenols. U.S. annual production is in excess of 20,000 tons. Pentachlorophenol melts at 190°C and is slightly soluble in water (14 mg/l). Pentachlorophenol is not detected by the 4-amino antipyrene method.

Pentachlorophenol is a bactericide and fungacide and is used for preservation of wood and wood products. It is competative with creosote in that application. It is also used as a preservative in glues, starches, and photographic papers. It is an effective algicide and herbicide.

Although data are available on the human toxicity effects of penta-chlorophenol, interpretation of data is frequently uncertain. Occupational exposure observations must be examined carefully because exposure to pentachlorophenol is frequently accompained by exposure to other wood preservatives. Additionally, experimental results and

occupational exposure observations must be examined carefully to make sure that observed effects are produced by the pentachlorophenol itself and not by the by-products which usually contaminate pentachlorophenol.

Acute and chronic toxic effects of pentachlorophenol in humans are similar; muscle weakness, headache, loss of appetite, abdominal pain, weight loss, and irritation of skin, eyes, and respiratory tract. Available literature indicates that pentachlorophenol does not accumulate in body tissues to any significant extent. Studies on laboratory animals of distribution of the compound in body tissues showed the highest levels of pentachlorophenol in liver, kidney, and intestine, while the lowest levels were in brain, fat, muscle, and bone.

Toxic effects of pentachlorophenol in aquatic organisms are much greater at pH of 6 where this weak acid is predominantly in the undissociated form than at pH of 9 where the ionic form predominates. Similar results were observed in mammals where oral lethal doses of pentachlorophenol were lower when the compound was administered in hydrocarbon solvents (un-ionized form) than when it was administered as the sodium salt (ionized form) in water.

There appear to be no significant teratogenic, mutagenic, or carcinogenic effects of pentachlorophenol.

For the protection of human health from the toxic properties of penta-chlorophenol ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.140 mg/l.

Only limited data are available for reaching conclusions about the behavior of pentachlorophenol in POTW. Pentachlorophenol has been found in the influent to POTW. In a study of one POTW the mean removal was 59 percent over a 7 day period. Trickling filters removed 44 percent of the influent pentachlorophenol, suggesting that biological degradation occurs. The same report compared removal of pentachlorophenol of the same plant and two additional POTW on a later date and obtained values of 4.4, 19.5 and 28.6 percent removal, the last value being for the plant which was 59 percent removal in the original study. Influent concentrations of pentachloropehnol ranged from 0.0014 to 0.0046 mg/l. Other studies, includng the general review of data relating molecular structure to biological oxidation, indicate that pentachlorophenol is not removed by biological treatment processes in POTW. Anaerobic digestion processes are inhibited by 0.4 mg/l pentachlorophenol.

The low water solubility and low volatility of pentachlorophenol lead to the expectation that most of the compund will remain in the sludge

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in a POTW. The effect on plants grown on land treated with pentachlorophenol - containing sludge is unpredicatable. Laboratory studies show that this compound affects crop germination at 5.4 mg/l. However, photodecomposition of pentachlorophenol occurs in sunlight. The effects of the various breakdown products which may remain in the soil was not found in the literature.

Phenol(65). Phenol, also called hydroxybenzene and carbolic acid, is a clear, colorless, hygroscopic, deliquescent, crystalline solid at room temperature. Its melting point is 43°C and its vapor pressure at room temperature is 0.35 mm Hg. It is very soluble in water (67 gm/l at 16°C) and can be dissolved in benzene, oils, and petroleum solids. Its formula is C_6H_5OH.

Although a small percent of the annual production of phenol is derived from coal tar as a naturally occuring product, most of the phenol is synthesized. Two of the methods are fusion of benzene sulfonate with sodium hydroxide, and oxidation of cumene followed by clevage with a catalyst. Annual production in the U.S. is in excess of one million tons. Phenol is generated during distillation of wood and the microbiological decomposition of organic matter in the mammalian intestinal tract.

Phenol is used as a disinfectant, in the manufacture of resins, dyestuffs, and pharmaceuticals, and in the photo processing industry. In this discussion, phenol is the specific compound which is separated by methylene chloride extraction of an acidified sample and identified and quantified by GC/MS. Phenol also contributes to the "Total Phenols", discussed elsewhere which are determined by the 4-AAP colorinmetric method.

Phenol exhibits acute and sub-acute toxicity in humans and laboratory animals. Acute oral doses of phenol in humans cause sudden collapse and unconsciousness by its action on the central nervous system. Death occurs by respiratory arrest. Sub-acute oral doses in mammals are rapidly absorbed then quickly distributed to various organs, then cleared from the body by urinary excretion and metabolism. Long term exposure by drinking phenol contaminated water has resulted in statistically significant increase in reported cases of diarrhea, mouth sores, and burning of the mouth. In laboratory animals long term oral administration at low levels produced slight liver and kidney damage. No reports were found regarding carcinogenicity of phenol administered orally - all carcinogenicity studies were skin tests.

For the protection of human health from phenol ingested through water and through contaminated aquatic organisms the concentration in water should not exceed 3.4 mg/l.

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Fish and other aquatic organisms demonstrated a wide range of sensitivities to phenol concentration. However, acute toxicity values were at moderate levels when compared to other organic priority pollutants.

Data have been developed on the behavior of phenol in POTW. Phenol is biodegradable by biota present in POTW. The ability of a POTW to treat phenol-bearing influents depends upon acclimation of the biota and the constancy of the phenol concentration. It appears that an induction period is required to build up the population of organisms which can degrade phenol. Too large a concentration will result in upset or pass through in the POTW, but the specific level causing upset depends on the immediate past history of phenol concentrations in the influent. Phenol levels as high as 200 mg/l have been treated with 95 percent removal in POTW, but more or less continuous presence of phenol is necessary to maintain the population of microorganisms that degrade phenol.

Phenol which is not degraded is expected to pass thorugh the POTW because of its very high water solubility. However, in POTW where chlorination is practiced for disinfection of the POTW effluent, chlorination of phenol may occur. The products of that reaction may be priority pollutants.

The EPA has developed data on influent and effluent concentrations of total phenols in a study of 103 POTW. However, the analytical procedure was the 4-AAP method mentioned earlier and not the GC/MS method specifically for phenol. Discussion of the study, which of course includes phenol, is presented under the pollutant heading "Total Phenols."

Phthalate Esters (66-71). Phthalic acid, or 1,2-benzenedicarboxylic acid, is one of three isomeric benzenedicarboxylic acids produced by the chemical industry. The other two isomeric forms are called isophthalic and terephathalic acids. The formula for all three acids is $C_6H_4(COOH)_2$. Some esters of phthalic acid are designated as priority pollutants. They will be discussed as a group here, and specific properties of individual phthalate esters will be discussed afterwards.

Phthalic acid esters are manufactured in the U.S. at an annual rate in excess of 1 billion pounds. They are used as plasticizers - primarily in the production of polyvinyl chloride (PVC) resins. The most widely used phthalate plasticizer is bis (2-ethylhexyl) phthalate (66) which accounts for nearly one third of the phthalate esters produced. This particular ester is commonly referred to as dioctyl phthalate (DOP) and should not be confused with one of the less used esters, di-n-octyl phthalate (69), which is also used as a plasticizer. In addition to these two isomeric dioctyl phthalates, four other esters,

also used primarily as plasticizers, are designated as priority pollutants. They are: butyl benzyl phthalate (67), di-n-butyl phthalate (68), diethyl phthalate (70), and dimethyl phthalate (71).

Industrially, phthalate esters are prepared from phthalic anhydride and the specific alcohol to form the ester. Some evidence is available suggesting that phthalic acid esters also may be synthesized by certain plant and animal tissues. The extent to which this occurs in nature is not known.

Phthalate esters used as plasticizers can be present in concentrations up to 60 percent of the total weight of the PVC plastic. The plasticizer is not linked by primary chemical bonds to the PVC resin. Rather, it is locked into the structure of intermeshing polymer molecules and held by van der Waals forces. The result is that the plasticizer is easily extracted. Plasticizers are responsible for the odor associated with new plastic toys or flexible sheet that has been contained in a sealed package.

Although the phthalate esters are not soluble or are only very slightly soluble in water, they do migrate into aqueous solutions placed in contact with the plastic. Thus industrial facilities with tank linings, wire and cable coverings, tubing, and sheet flooring of PVC are expected to discharge some phthalate esters in their raw waste. In addition to their use as plasticizers, phthalate esters are used in lubricating oils and pesticide carriers. These also can contribute to industrial discharge of phthalate esters.

From the accumulated data on acute toxicity in animals, phthalate esters may be considered as having a rather low order of toxicity. Human toxicity data are limited. It is thought that the toxic effects of the esters is most likely due to one of the metabolic products, in particular the monoester. Oral acute toxicity in animals is greater for the lower molecular weight esters than for the higher molecular weight esters.

Orally administered phthalate esters generally produced enlargeing of liver and kidney, and atrophy of testes in laboratory animals. Specific esters produced enlargement of heart and brain, spleenitis, and degeneration of central nervous system tissue.

Subacute doses administered orally to laboratory animals produced some decrease in growth and degeneration of the testes. Chronic studies in animals showed similar effects to those found in acute and subacute studies, but to a much lower degree. The same organs were enlarged, but pathological changes were not usually detected.

A recent study of several phthalic esters produced suggestive but not conclusive evidence that dimethyl and diethyl phthalates have a cancer

liability. Only four of the six priority pollutant esters were included in the study. Phthalate esters do bioconcentrate in fish. The factors, weighted for relative consumption of various aquatic and marine food groups, are used to calculate ambient water quality criteria for four phthalate esters. The values are included in the discussion of the specific esters.

Studies of toxicity of phthalate esters in freshwater and salt water organisms are scarce. A chronic toxicity test with bis(2-ethylhexyl) phthalate showed that significant reproductive impairment occurred at 3 mg/l in the freshwater crustacean, Daphnia magna. In acute toxicity studies, saltwater fish and organisms showed sensitivity differences of up to eight-fold to butyl benzyl, diethyl, and dimethyl phthalates. This suggests that each ester must be evaluated individually for toxic effects.

The behavior of phthalate esters in POTW has not been studied. However, the biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewater. Three of the phthalate esters were studied. Bis(2-ethylhexyl) phthalate was found to be degraded slightly or not at all and its removal by biological treatment in a POTW is expected to be slight or zero. Di-n-butyl phthalate and diethyl phthalate were degraded to a moderate degree and their removal by biological treatment in a POTW is expected to occur to a moderate degree. Using these data and other observations relating molecular structure to ease of biochemical degradation of other organic pollutants, the conclusion was reached that butyl benzyl phthalate and dimethyl phthalate would be removed in a POTW to a moderate degree by biological treatment. On the same basis, it was concluded that di-n-octyl phthalate would be removed to a slight degree or not at all.

No information was found on possible interference with POTW operation or the possible effects on sludge by the phthalate esters. The water insoluble phthalate esters - butylbenzyl and di-n-octyl phthalate - would tend to remain in sludge, whereas the other four priority pollutant phthalate esters with water solubilities ranging from 50 mg/l to 4.5 mg/l would probably pass through into the POTW effluent.

Bis (2-ethylhexyl) phthalate(66). In addition to the general remarks and discussion on phthalate esters, specific information on bis(2-ethylhexyl) phthalate is provided. Little information is available about the physical properties of bis(2-ethylhexyl) phthalate. It is a liquid boiling at 387°C at 5mm Hg and is insoluble in water. Its formula is $C_6H_4(COOC_8H_{17})_2$. This priority pollutant constitutes about one third of the phthalate ester production in the U.S. It is commonly referred to as dioctyl phthalate, or DOP, in the plastics industry where it is the most extensively used compound for the

plasticization of polyvinyl chloride (PVC). Bis(2-ethylhexyl) phthalate has been approved by the FDA for use in plastics in contact with food. Therefore, it may be found in wastewaters coming in contact with discarded plastic food wrappers as well as the PVC films and shapes normally found in industrial plants. This priority pollutant is also a commonly used organic diffusion pump oil where its low vapor pressure is an advantage.

For the protection of human health from the toxic properties of bis(2-ethylhexyl) phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 10 mg/l.

Although the behavior of bis(2-ethylhexyl) phthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. In fresh water with a non-acclimated seed culture no biochemical oxidation was observed after 5, 10, and 20 days. However, with an acclimated seed culture, biological oxidation occurred to the extents of 13, 0, 6, and 23 of theoretical after 5, 10, 15 and 20 days, respectively. Bis(2-ethylhexyl) phthalate concentrations were 3 to 10 mg/l. Little or no removal of bis(2-ethylhexyl) phthalate by biological treatment in POTW is expected.

Butyl benzyl phthalate(67). In addition to the general remarks and discussion on phthalate esters, specific information on butyl benzyl phthalate is provided. No information was found on the physical properties of this compound.

Butyl benzyl phthalate is used as a plasticizer for PVC. Two special applications differentiate it from other phthalate esters. It is approved by the U.S. FDA for food contact in wrappers and containers; and it is the industry standard for plasticization of vinyl flooring because it provides stain resistance.

No ambient water quality criterion is proposed for butyl benzyl phthalate.

Butylbenzylphthalate removal in POTW by biological treatment in a POTW is expected to occur to a moderate degree.

Di-n-butyl phthalate (68). In addition to the general remarks and discussion on phthalate esters, specific information on di-n-butyl phthalate (DBP) is provided. DBP is a colorless, oily liquid, boiling at 340°C. Its water solubility at room temperature is reported to be 0.4 g/l and 4.5g/l in two different chemistry handbooks. The formula for DBP, $C_6H_4(COOC_4H_9)_2$ is the same as for its isomer, di-isobutyl

phthalate. DBP production is one to two percent of total U.S. phthalate ester production.

Dibutyl phthalate is used to a limited extent as a plasticizer for polyvinylchloride (PVC). It is not approved for contact with food. It is used in liquid lipsticks and as a diluent for polysulfide dental impression materials. DBP is used as a plasticizer for nitrocellulose in making gun powder, and as a fuel in solid propellants for rockets. Further uses are insecticides, safety glass manufacture, textile lubricating agents, printing inks, adhesives, paper coatings and resin solvents.

For protection of human health from the toxic properties of dibutyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 5 mg/l.

Although the behavior of di-n-butyl phthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. Biochemical oxidation of 35, 43, and 45 percent of theoretical oxidation were obtained after 5, 10, and 20 days, respectively, using sewage microorganisms as an unacclimated seed culture.

Biological treatment in POTW is expected to remove di-n-butyl phthalate to a moderate degree.

Di-n-octyl phthalate(69). In addition to the general remarks and discussion on phthalate esters, specific information on di-n-octyl phthalate is provided. Di-n-octyl phthalate is not to be confused with the isomeric bis(2-ethylhexyl) phthalate which is commonly referred to in the plastics industry as DOP. Di-n-octyl phthalate is a liquid which boils at 220°C at 5 mm Hg. It is insoluble in water. Its molecular formula is $C_6H_4(COOC_8H_{17})_2$. Its production constitutes about one percent of all phthalate ester production in the U.S.

Industrially, di-n-octyl phthalate is used to plasticize polyvinyl chloride (PVC) resins.

No ambient water quality criterion is proposed for di-n-octyl phthalate.

Biological treatment in POTW is expected to lead to little or no removal of di-n-octyl phthalate.

Diethyl phthalate (70). In addition to the general remarks and discussion on phthalate esters, specific information on diethyl phthalate is provided. Diethyl phthalate, or DEP, is a colorless

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liquid boiling at 296°C, and is insoluble in water. Its molecular formula is $C_6H_4(COOC_2H_5)_2$. Production of diethyl phthalate constitutes about 1.5 percent of phthalate ester production in the U.S.

Diethyl phthalate is approved for use in plastic food containers by the U.S. FDA. In addition to its use as a polyvinylchloride (PVC) plasticizer, DEP is used to plasticize cellulose nitrate for gun powder, to dilute polysulfide dental impression materials, and as an accelerator for dying triacetate fibers. An additional use which would contribute to its wide distribution in the environment is as an approved special denaturant for ethyl alcohol. The alcohol-containing products for which DEP is an approved denaturant include a wide range of personal care items such as bath preparations, bay rum, colognes, hair preparations, face and hand creams, perfumes and toilet soaps. Additionally, this denaturant is approved for use in biocides, cleaning solutions, disinfectants, insecticides, fungicides, and room deodorants which have ethyl alcohol as part of the formulation. It is expected, therefore, that people and buildings would have some surface loading of this priority pollutant which would find its way into raw wastewaters.

For the protection of human health from the toxic properties of diethyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 60 mg/l.

Although the behavior of diethylphthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. Biochemical oxidation of 79, 84, and 89 percent of theoretical was observed after 5, 5, and 20 days, respectively. Biological treatment in POTW is expected to lead to a moderate degree of removal of diethylphthalate.

Dimethyl phthalate (71). In addition to the general remarks and discussion on phthalate esters, specific information on dimethyl phthalate (DMP) is provided. DMP has the lowest molecular weight of the phthalate esters - N.W. = 194 compared to M.W. of 391 for bis(2-ethylhexyl)phthalate. DMP has a boiling point of 282°C. It is a colorless liquid, soluble in water to the extent of 5 mg/l. Its molecular formula is $C_6H_4(COOCH_3)_2$.

Dimethyl phthalate production in the U.S. is just under one percent of total phthalate ester production. DMP is used to some extent as a plasticizer in cellulosics. However, its principle specific use is for dispersion of polyvinylidene fluoride (PVDF). PVDF is resistant to most chemicals and finds use as electrical insulation, chemical process equipment (particularly pipe), and as a base for long-life

finishes for exterior metal siding. Coil coating techniques are used to apply PVDF dispersions to aluminum or galvanized steel siding.

For the protection of human health from the toxic properties of dimethyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 160 mg/l.

Biological treatment in POTW is expected to provide a moderate degree of removal of dimethyl phthalate.

Polynuclear Aromatic Hydrocarbons(72-84). The polynuclear aromatic hydrocarbons (PAH) selected as priority pollutants are a group of 13 compounds consisting of substituted and unsubstituted polycyclic aromatic rings. The general class of PAH includes hetrocyclics, but none of those were selected as priority pollutants. PAH are formed as the result of incomplete combustion when organic compounds are burned with insufficient oxygen. PAH are found in coke oven emissions, vehicular emissions, and volatile products of oil and gas burning. The compounds chosen as priority pollutants are listed with their structural formula and melting point (m.p.). All are insoluble in water.

72   Benzo(a)anthrancene (1,2-benzanthracene)

m.p. 162°C
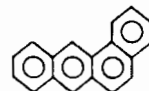
73   Benzo(a)pyrene (3,4-benzopyrene)

m.p. 176°C
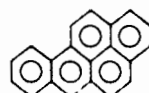
74   3,4-Benzofluoranthene

m.p. 168°C
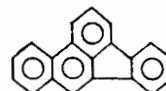
75   Benzo(k)fluoranthene (11,12-benzofluoranthene)

m.p. 217°C
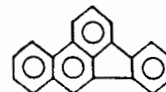
76   Chrysene (1,2-benzphenanthrene)

m.p. 255°C

77   Acenaphthylene

HC=CH

m.p. 92°C
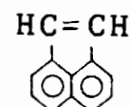
78   Anthracene

m.p. 216°C

399
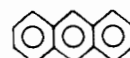
79   Benzo(ghi)perylene (1,12-benzoperylene)

        m.p. not reported
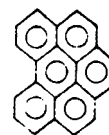
80   Fluorene (alpha-diphenylenemethane)

        m.p. 116°C
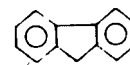
81   Phenanthrene

        m.p. 101°C
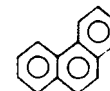
82   Dibenzo(a,h)anthracene (1,2,5,6-dibenzoanthracene)

        m.p. 269°C
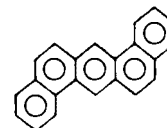
83   Indeno(1,2,3-cd)pyrene (2,3-o-phenyleneperylene)

        m.p. not available
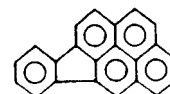
84   Pyrene

        m.p. 156°C

Some of these priority pollutants have commercial or industrial uses. Benzo(a)anthracene, benzo(a)pyrene, chrysene, anthracene, dibenzo(a,h)anthracene, and pyrene are all used as antioxidants. Chrysene, acenaphthylene, anthracene, fluorene, phenanthrene, and pyrene are all used for synthesis of dyestuffs or other organic chemicals. 3,4-Benzofluoranthrene, benzo(k)fluoranthene, benzo(ghi)perylene, and indeno (1,2,3-cd)pyrene have no known industrial uses, according to the results of a recent literature search.

Several of the PAH priority pollutants are found in smoked meats, in smoke flavoring mixtures, in vegetable oils, and in coffee. They are found in soils and sediments in river beds. Consequently, they are also found in many drinking water supplies. The wide distribution of these pollutants in complex mixtures with the many other PAHs which have not been designated as priority pollutants results in exposures

by humans that cannot be associated with specific individual compounds.

The screening and verification analysis procedures used for the organic priority pollutants are based on gas chromatography (GC). Three pairs of the PAH have identical elution times on the column specified in the protocol, which means that the parameters of the pair are not differentiated. For these three pairs [anthracene (78) – phenanthrene (81); 3,4-benzofluoranthene (74) – benzo(k)fluoranthene (75); and benzo(a)anthracene (72) – chrysene (76)] results are obtained and reported as "either-or." Either both are present in the combined concentration reported, or one is present in the concentration reported. When detections below reportable limits are recorded no further analysis is required. For samples where the concentrations of coeluting pairs have a significant value, additional analyses are conducted, using different procedures that resolve the particular pair.

There are no studies to document the possible carcinogenic risks to humans by direct ingestion. Air pollution studies indicate an excess of lung cancer mortality among workers exposed to large amounts of PAH containing materials such as coal gas, tars, and coke-oven emissions. However, no definite proof exists that the PAH present in these materials are responsible for the cancers observed.

Animal studies have demonstrated the toxicity of PAH by oral and dermal administration. The carcinogenicity of PAH has been traced to formation of PAH metabolites which, in turn, lead to tumor formation. Because the levels of PAH which induce cancer are very low, little work has been done on other health hazards resulting from exposure. It has been established in animal studies that tissue damage and systemic toxicity can result from exposure to non-carcinogenic PAH compounds.

Because there were no studies available regarding chronic oral exposures to PAH mixtures, proposed water quality criteria were derived using data on exposure to a single compound. Two studies were selected, one involving benzo(a)pyrene ingestion and one involving dibenzo(a,h)anthracene ingestion. Both are known animal carcinogens.

For the maximum protection of human health from the potential carcinogenic effects of exposure to polynuclear aromatic hydrocarbons (PAH) through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of PAH estimated to result in additional risk of 1 in 100,000 were derived by the EPA and the Agency is considering setting criteria at an interim target risk level in the range of 10^{-5}, 10^{-6}, or 10^{-7} with corresponding criteria of 0.0000097 mg/l, 0.00000097 mg/l, and 0.000000097 mg/l, respectively.

No standard toxicity tests have been reported for freshwater or saltwater organisms and any of the 13 PAH discussed here.

The behavior of PAH in POTW has received only a limited amount of study. It is reported that up to 90 percent of PAH entering a POTW will be retained in the sludge generated by conventional sewage treatment processes. Some of the PAH can inhibit bacterial growth when they are present at concentrations as low as 0.018 mg/l. Biological treatment in activated sludge units has been shown to reduce the concentration of phenanthrene and anthracene to some extent. However, a study of biochemcial oxidation of fluorene on a laboratory scale showed no degradation after 5, 10, and 20 days. On the basis of that study and studies of other organic priority pollutants, some general observations were made relating molecular structure to ease of degradation. Those observations lead to the conclusion that the 13 PAH selected to represent that group as priority pollutants will be removed only slightly or not at all by biological treatment methods in POTW. Based on their water insolubility and tendency to attach to sediment particles very little pass through of PAH to POTW effluent is expected.

No data are available at this time to support any conclusions about contamination of land by PAH on which sewage sludge containing PAH is spread.

Tetrachloroethylene(85). Tetrachloroethylene (CCl_2CCl_2), also called perchloroethylene and PCE, is a colorless nonflammable liquid produced mainly by two methods - chlorination and pyrolysis of ethane and propane, and oxychlorination of dichloroethane. U.S. annual production exceeds 300,000 tons. PCE boils at 121°C and has a vapor pressure of 19 mm Hg at 20°C. It is insoluble in water but soluble in organic solvents.

Approximately two-thirds of the U.S. production of PCE is used for dry cleaning. Textile processing and metal degreasing, in equal amounts consume about one-quarter of the U.S. production.

The principal toxic effect of PCE on humans is central nervous system depression when the compound is inhaled. Headache, fatigue, sleepiness, dizziness and sensations of intoxication are reported. Severity of effects increases with vapor concentration. High integrated exposure (concentration times duration) produces kidney and liver damage. Very limited data on PCE ingested by laboratory animals indicate liver damage occurs when PCE is administered by that route. PCE tends to distribute to fat in mammalian bodies.

One report found in the literature suggests, but does not conclude, that PCE is teratogenic. PCE has been demonstrated to be a liver carcinogen in B6C3-F1 mice.

For the maximum protection of human health from the potential carcinogenic effects of exposure to tetrachloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of tetrachloroethylene estimated to result in additional lifetime cancer risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.000020 mg/l, 0.00020 mg/l, and 0.0020 mg/l, respectively.

No data were found regarding the behavior of PCE in POTW. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusions reached by the study of the limited data is that biological treatment produces a moderate removal of PCE in POTW by degradation. No information was found to indicate that PCE accumulates in the sludge, but some PCE is expected to be adsorbed onto settling particles. Some PCE is expected to be volatilized in aerobic treatment processes and little, if any, is expected to pass through into the effluent from the POTW.

Toluene(86). Toluene is a clear, colorless liquid with a benzene like odor. It is a naturally occuring compound derived primarily from petroleum or petrochemical processes. Some toluene is obtained from the manufacture of metallurgical coke. Toluene is also referred to as totuol, methylbenzene, methacide, and phenymethane. It is an aromatic hydrocarbon with the formula $C_6H_5CH_3$. It boils at 111°C and has a vapor pressure of 30 mm Hg at room temperature. The water solubility of toluene is 535 mg/l, and it is miscible with a variety of organic solvents. Annual production of toluene in the U.S. is greater than 2 million metric tons. Approximately two-thirds of the toluene is converted to benzene and the remaining 30 percent is divided approximately equally into chemical manufacture, and use as a paint solvent and aviation gasoline additive. An estimated 5,000 metric tons is discharged to the environment annually as a constituent in wastewater.

Most data on the effects of toluene in human and other mammals have been based on inhalation exposure or dermal contact studies. There appear to be no reports of oral administration of toluene to human subjects. A long term toxicity study on female rats revealed no adverse effects on growth, mortality, appearance and behavior, organ to body weight ratios, blood-urea nitrogen levels, bone marrow counts, peripheral blood counts, or morphology of major organs. The effects of inhaled toluene on the central nervous system, both at high and low concentrations, have been studied in humans and animals. However, ingested toluene is expected to be handled differently by the body because it is absorbed more slowly and must first pass through the

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liver before reaching the nervous system. Toluene is extensively and rapidly metabolized in the liver. One of the principal metabolic products of toluene is benzoic acid, which itself seems to have little potential to produce tissue injury.

Toluene does not appear to be teratogenic in laboratory animals or man. Nor is there any conclusive evidence that toluene is mutagenic. Toluene has not been demonstrated to be positive in any in vitro mutagenicity or carcinogenicity bioassay system, nor to be carcinogenic in animals or man.

Toluene has been found in fish caught in harbor waters in the vicinity of petroleum and petrochemical plants. Bioconcentration studies have not been conducted, but bioconcentration factors have been calculated on the basis of the octanol-water partition coefficient.

For the protection of human health from the toxic properties of toluene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 12.4 mg/l.

Acute toxicity tests have been conducted with toluene and a variety of freshwater fish and Daphnia magna. The latter appears to be significantly more resistant than fish. No test results have been reported for the chronic effects of toluene on freshwater fish or invertebrate species.

No detailed study of toluene behavior in POTW is available. However, the biochemical oxidation of many of the priority pollutants has been investigated in laboratory scale studies at concentrations greater than those expected to be contained by most municipal wastewaters. At toluene concentrations ranging from 3 to 250 mg/l biochemical oxidation proceeded to fifty percent of theroetical or greater. The time period varied from a few hours to 20 days depending on whether or not the seed culture was acclimated. Phenol adapted acclimated seed cultures gave the most rapid and extensive biochemical oxidation. The conclusion reached by study of the limited data is that biological treatment produces moderate removal of toluene in POTW. The volatility and relatively low water solubility of toluene lead to the expectation that aeration processes will remove significant quantities of toluene from the POTW.

Trichloroethylene(87). Trichloroethylene (1,1,2-trichloroethylene or TCE) is a clear colorless liquid boiling at 87°C. It has a vapor pressure of 77 mm Hg at room temperature and is slightly soluble in water (1 g/l). U.S. production is greater than 0.25 million metric tons annually. It is produced from tetrachloroethane by treatment with lime in the presence of water.

TCE is used for vapor phase degreasing of metal parts, cleaning and drying electronic components, as a solvent for paints, as a refrigerant, for extraction of oils, fats, and waxes, and for dry cleaning. Its widespread use and relatively high volability result in detectable levels in many parts of the environment.

Data on the effects produced by ingested TCE are limted. Most studies have been directed at inhalation exposure. Nervous system disorders and liver damage are frequent results of inhalation exposure. In the short term exposures, TCE acts as a central nervous system depressant - it was used as an anesthetic before its other long term effects were defined.

TCE has been shown to induce transformation in a highly sensitive in vitro Fischer rat embryo cell system (F1706) that is used for identifying carcinogens. Severe and persintant toxicity to the liver was recently demonstrated when TCE was shown to produce carcinoma of the liver in mouse strain B6C3Fl. One systematic study of TCE exposure and the incidence of human cancer was based on 518 men exposed to TCE. The authors of that study concluded that although the cancer risk to man cannot be ruled out, exposure to low levels of TCE probably does not present a very serious and general cancer hazard.

TCE is bioconcentrated in aquatic species, making the consumption of such species by humans a significant source of TCE. For the protection of human health from the potential-carcinogenic effects of exposure to trichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of trichloroethylene estimated to result in additional lifetime cancer risk of 1 in 100,000 corresponds to an ambient water concentration of 0.00021 mg/l.

Only a very limited amount of data on the effects of TCE on freshwater aquatic life are available. One species of fish (fathead minnows) showed a loss of equilibrium at concentrations below those resulting in lethal effects.

The behavior of trichloroethylene in POTW has not been studied. However, in laboratory scale studies of organic priority pollutants, TCE was subjected to biochemical oxidation conditions. After 5, 10, and 20 days no biochemical oxidation occurred. On the basis of this study and general observations relating molecular structure to ease of degradation, the conclusion is reached that TCE would undergo no removal by biological treatment in a POTW. The volatility and relatively low water solubility of TCE is expected to result in volatilization of some of the TCE in aeration steps in a POTW.

Antimony(114). Antimony (chemical name - stibium, symbol Sb) classified as a non-metal or metalloid, is a silvery white , brittle,

crystalline solid. Antimony is found in small ore bodies throughout the world. Principal ores are oxides of mixed antimony valences, and an oxysulfide ore. Complex ores with metals are important because the antimony is recovered as a by-product. Antimony melts at 631°C, and is a poor conductor of electricity and heat.

Annual U.S. consumption of primary antimony ranges from 10,000 to 20,000 tons. About half is consumed in metal products - mostly antimonial lead for lead acid storage batteries, and about half in non - metal products. A principal compound is antimony trioxide which is used as a flame retardant in fabrics, and as an opacifier in glass, ceramincs, and enamels. Several antimony compounds are used as catalysts in organic chemicals synthesis, as fluorinating agents (the antimony fluoride), as pigments, and in fireworks. Semiconductor applications are economically significant.

Essentially no information on antimony - induced human health effects has been derived from community epidemiolocy studies. The available data are in literature relating effects observed with therapeutic or medicinal uses of antimony compounds and industrial exposure studies. Large therapeutic doses of antimonial compounds, usually used to treat schistisomiasis, have caused severe nausea, vomiting, convulsions, irregular heart action, liver damage, and skin rashes. Studies of acute industrial antimony poisoning have revealed loss of appetitie, diarrhea, headache, and dizziness in addition to the symptoms found in studies of therapeutic doses of antimony.

For the protection of human health from the toxic properties of antimony ingested through water and through contaminated aquatic organisms the ambient water criterion is determined to be 0.145 mg/l.

Very little information is available regarding the behavior of antimony in POTW. The limited solubility of most antimony compounds expected in POTW, i.e. the oxides and sulfides, suggests that at least part of the antimony entering a POTW will be precipitated and incorporated into the sludge. However, some antimony is expected to remain dissolved and pass through the POTW into the effluent. Antimony compounds remaining in the sludge under anaerobic conditions may be connected to stibine (SbH_3), a very soluble and very toxic compound. There are no data to show antimony inhibits any POTW processes. Antimony is not known to be essential to the growth of plants, and has been reported to be moderately toxic. Therefore, sludge containing large amounts of antimony could be detrimental to plants if it is applied in large amounts to cropland.

Arsenic(115). Arsenic (chemical symbol As), is classified as a non-metal or metalloid. Elemental arsenic normally exists in the alpha-crystalline metallic form which is steel gray and brittle, and in the beta form which is dark gray and amorphous. Arsenic sublimes at

615°C.   Arsenic is widely distributed throughout the world in a large number of minerals. The most important commercial source of arsenic is as a by-product from treatment of copper, lead, cobalt, and gold ores.   Arsenic is usually marketed as the trioxide (As_2O_3).   Annual U.S. production of the trioxide approaches 40,000 tons.

The principal use of arsenic is in agricultural chemicals (herbicides) for controlling weeds in cotton fields.   Arsenicals have various applications in medicinal and veterinary use, as wood preservatives, and in semiconductors.

The effects of arsenic in humans were known by the ancient Greeks and Romans.   The principal toxic effects are gastrointestinal disturbances. Breakdown of red blood cells occurs. Symptoms of acute poisoning include vomiting, diarrhea, abdominal pain, lassitude, dizziness, and headache. Longer exposure produced dry, falling hair, brittle, loose nails, eczema, and exfoliation.   Arsenicals also exhibit teratogenic and mutagenic effects in humans.   Oral administration of arsenic compounds has been associated clinically with skin cancer for nearly a hundred years.   Since 1888 numerous studies have linked occupational exposure to, and therapeutic administration of arsenic compounds to increased incidence of respiratory and skin cancer.

For the maximum protection of human health from the potential carcinogenic effects of exposure to arsenic through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of arsenic estimated to result in additional lifetime cancer risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.0000002 mg/l, 0.000002 mg/l, and 0.00002 mg/l, respectively.

A few studies have been made regarding the behavior of arsenic in POTW.   One EPA survey of 9 POTW reported influent concentrations ranging from 0.0005 to 0.693 mg/l; effluents from 3 POTW having biological treatment contained 0.0004 – 0.01 mg/l; 2 POTW showed arsenic removal efficiencies of 50 and 71 percent in biological treatment.   Inhibition of treatment processes by sodium arsenate is reported to occur at 0.1 mg/l in activated sludge, and 1.6 mg/l in anaerobic digestion processes. In another study based on data from 60 POTW, arsenic in sludge ranged from 1.6 to 65.6 mg/kg and the median value was 7.8 mg/kg. Arsenic in sludge spread on cropland may be taken up by plants grown on that land. Edible plants can take up arsenic, but normally their growth is inhibited before the plants are ready for harvest.

Cadmium(118).   Cadmium is a relatively rare metallic element that is seldom found in sufficient quantities in a pure state to warrant mining or extraction from the earth's surface. It is found in trace

amounts of about 1 ppm throughout the earth's crust. Cadmium is, however, a valuable by-product of zinc production.

Cadmium is used primarily as an electroplated metal, and is found as an impurity in the secondary refining of zinc, lead, and copper.

Cadmium is an extremely dangerous cumulative toxicant, causing progressive chronic poisoning in mammals, fish, and probably other organisms.

Toxic effects of cadmium on man have been reported from throughout the world. Cadmium may be a factor in the development of such human pathological conditions as kidney disease, testicular tumors, hypertension, arteriosclerosis, growth inhibition, chronic disease of old age, and cancer. Cadmium is normally ingested by humans through food and water as well as by breathing air contaminated by cadmium dust. Cadmium is cumulative in the liver, kidney, pancreas, and thyroid of humans and other animals. A severe bone and kidney syndrome known as itai-itai disease has been documented in Japan as caused by cadmium ingestion via drinking water and contaminated irrigation water. Ingestion of as little as 0.6 mg/day has produced the disease. Cadmium acts synergistically with other metals. Copper and zinc substantially increase its toxicity.

Cadmium is concentrated by marine organisms, particularly molluscs, which accumulate cadmium in calcareous tissues and in the viscera. A concentration factor of 1000 for cadmium in fish muscle has been reported, as have concentration factors of 3000 in marine plants and up to 29,600 in certain marine animals. The eggs and larvae of fish are apparently more sensitive than adult fish to poisoning by cadmium, and crustaceans appear to be more sensitive than fish eggs and larvae.

For the protection of human health from the toxic properties of cadmium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.010 mg/l.

Cadmium is not destroyed when it is introduced into a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. In addition, it can interfere with the POTW treatment process.

In a study of 189 POTW, 75 percent of the primary plants, 57 percent of the trickling filter plants, 66 percent of the activated sludge plants and 62 percent of the biological plants allowed over 90 percent of the influent cadmium to pass thorugh to the POTW effluent. Only 2 of the 189 POTW allowed less than 20 percent pass-through, and none less than 10 percent pass-through. POTW effluent concentrations ranged from 0.001 to 1.97 mg/l (mean 0.028 mg/l, standard deviation 0.167 mg/l).

Cadmium not passed through the POTW will be retained in the sludge where it is likely to build up in concentration. Cadmium contamination of sewage sludge limits its use on land since it increases the level of cadmium in the soil. Data show that cadmium can be incorporated into crops, including vegetables and grains, from contaminated soils. Since the crops themselves show no adverse effects from soils with levels up to 100 mg/kg cadmium, these contaminated crops could have a significant impact on human health.

Chromium(119). Chromium is an elemental metal usually found as a chromite ($FeO \cdot Cr_2O_3$). The metal is normally produced by reducing the oxide with aluminum. A significant proportion of the chromium used is in the form of compounds such as sodium dichromate (Na_2CrO_4), and chromic acid (CrO_3) - both are hexavalent chromium compounds.

Chromium is found as an alloying component of many steels and its compounds are used in electroplating baths, and as corrosion inhibitors for closed water circulation systems.

The two chromium forms most frequently found in industry wastewaters are hexavalent and trivalent chromium. Hexavalent chromium is the form used for metal treatments. Some of it is reduced to trivalent chromium as part of the process reaction. The raw wastewater containing both valence states is usually treated first to reduce remaining hexavalent to trivalent chromium, and second to precipitate the trivalent form as the hydroxide. The hexavalent form is not removed by lime treatment.

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. Hexavalent chromium is a known human carcinogen. Levels of chromate ions that show no effect in man appear to be so low as to prohibit determination, to date.

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 the effect of water hardness. Studies have shown that trivalent chromium is more toxic to fish of some types than is hexavalent chromium. Hexavalent chromium retards growth of one fish species at 0.0002 mg/l. Fish food

organisms and other lower forms of aquatic life are extremely
sensitive to chromium. Therefore, both hexavalent and trivalent
chromium must be considered harmful to particular fish or organisms.

For the protection of human health from the toxic properties of
chromium (except hexavalent chromium) ingested through water and
contaminated aquatic organisms, the recommended water qualtiy
criterion is 0.050 mg/l.

For the maximum protection of human health from the potential
carcinogenic effects of exposure to hexavalent chromium through
ingestion of water and contaminated aquatic organisms, the ambient
water concentration is zero.

Chromium is not destroyed when treated by POTW (although the oxidation
state may change), and will either pass through to the POTW effluent
or be incorporated into the POTW sludge. Both oxidation states can
cause POTW treatment inhibition and can also limit the usefuleness of
municipal sludge.

Influent concentrations of chromium to POTW facilities have been
observed by EPA to range from 0.005 to 14.0 mg/l, with a median
concentration of 0.1 mg/l. The efficiencies for removal of chromium
by the activated sludge process can vary greatly, depending on
chromium concentration in the influent, and other operating conditions
at the POTW. Chelation of chromium by organic matter and dissolution
due to the presence of carbonates can cause deviations from the
predicted behavior in treatment systems.

The systematic presence of chromium compounds will halt nitrification
in a POTW for short periods, and most of the chromium will be retained
in the sludge solids. Hexavalent chromium has been reported to
severely affect the nitrification process, but trivalent chromium has
litte or no toxicity to activated sludge, except at high
concentrations. The presence of iron, copper, and low pH will
increase the toxicity of chromium in a POTW by releasing the chromium
into solution to be ingested by microorganisms in the POTW.

The amount of chromium which passes through to the POTW effluent
depends on the type of treatment processes used by the POTW. In a
study of 240 POTW 56 percent of the primary plants allowed more than
80 percent pass through to POTW effluent. More advanced treatment
results in less pass-through. POTW effluent concentrations ranged
from 0.003 to 3.2 mg/l total chromium (mean = 0.197, standard
deviation = 0.48), and from 0.002 to 0.1 mg/l hexavalent chromium
(mean = 0.017, standard deviation = 0.020).

Chromium not passed through the POTW will be retained in the sludge,
where it is likely to build up in concentration. Sludge

concentrations of total chromium of over 20,000 mg/kg (dry basis) have been observed. Disposal of sludges containing very high concentrations of trivalent chromium can potentially cause problems in uncontrollable landfills. Incineration, or similar destructive oxidation processes can produce hexavalent chromium from lower valance states. Hexavalent chromium is potentially more toxic than trivalent chromium. In cases where high rates of chrome sludge application on land are used, distinct growth inhibition and plant tissue uptake have been noted.

Pretreatment of discharges substantially reduces the concentration of chromium in sludge. In Buffalo, New York, pretreatment of electroplating waste resulted in a decrease in chromium concentrations in POTW sludge from 2,510 to 1,040 mg/kg. A similar reduction occurred in Grand Rapids, Michigan, POTW where the chromium concentration in sludge decreased from 11,000 to 2,700 mg/kg when pretreatment was made a requirement.

Copper(120). Copper is a metallic element that sometimes is found free, as the native metal, and is also found in minerals such as cuprite (Cu_2O), malechite [$CuCO_3 \cdot Cu(OH)_2$], azurite [$2CuCO_3 \cdot Cu(OH)_2$], chalcopyrite ($CuFeS_2$), and bornite (Cu_5FeS_4). Copper is obtained from these ores by smelting, leaching, and electrolysis. It is used in the plating, electrical, plumbing, and heating equipment industries, as well as in insecticides and fungicides.

Traces of copper are found in all forms of plant and animal life, and the metal 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. To prevent this adverse organoleptic effect of copper in water, a criterion of 1 mg/l has been established.

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 calcium are synergistic in their toxic effect on fish.

Relatively high concentrations of copper may be tolerated by adult fish for short periods of time; the critical effect of copper appears to be its higher toxicity to young or juvenile fish. Concentrations of 0.02 to 0.031 mg/l have proved fatal to some common fish species. In general the salmonoids are very sensitive and the sunfishes are less sensitive to copper.

The recommended criterion to protect saltwater aquatic life is 0.00097 mg/l as a 24-hour average, and 0.018 mg/l maximum concentration.

Copper salts cause undesirable color reactions in the food industry and cause pitting when deposited on some other metals such as aluminum and galvanized steel.

Irrigation water containing more than minute quantities of copper can be detrimental to certain crops. Copper appears in all soils, and its concentration ranges from 10 to 80 ppm. In soils, copper occurs in association with hydrous oxides of manganese and iron, and also as soluble and insoluble complexes with organic matter. Copper is essential to the life of plants, and the normal range of concentration in plant tissue is from 5 to 20 ppm. Copper concentrations in plants normally do not build up to high levels when toxicity occurs. For example, the concentrations of copper in snapbean leaves and pods was less than 50 and 20 mg/kg, respectively, under conditions of severe copper toxicity. Even under conditions of copper toxicity, most of the excess copper accumulates in the roots; very little is moved to the aerial part of the plant.

Copper is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with the POTW treatment processes and can limit the usefulness of municipal sludge.

The influent concentration of copper to POTW facilities has been observed by the EPA to range from 0.01 to 1.97 mg/l, with a median concentration of 0.12 mg/l. The copper that is removed from the influent stream of a POTW is adsorbed on the sludge or appears in the sludge as the hydroxide of the metal. Bench scale pilot studies have shown that from about 25 percent to 75 percent of the copper passing through the activated sludge process remains in solution in the final effluent. Four-hour slug dosages of copper sulfate in concentrations exceeding 50 mg/l were reported to have severe effects on the removal efficiency of an unacclimated system, with the system returning to normal in about 100 hours. Slug dosages of copper in the form of copper cyanide were observed to have much more severe effects on the activated sludge system, but the total system returned to normal in 24 hours.

In a recent study of 268 POTW, the median pass-through was over 80 percent for primary plants and 40 to 50 percent for trickling filter, activated sludge, and biological treatment plants. POTW effluent concentrations of copper ranged from 0.003 to 1.8 mg/l (mean 0.126, standard deviation 0.242).

Copper which does not pass through the POTW will be retained in the sludge where it will build up in concentration. The presence of excessive levels of copper in sludge may limit its use on cropland. Sewage sludge contains up to 16,000 mg/kg of copper, with 730 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which usually range from 18 to 80 mg/kg. Experimental data indicate that when dried sludge is spread over tillable land, the copper tends to remain in place down to the depth of tillage, except for copper which is taken up by plants grown in the soil. Recent investigation has shown that the extractable copper content of sludge-treated soil decreased with time, which suggests a reversion of copper to less soluble forms was occurring.

Cyanide(121). Cyanides are among the most toxic of pollutants commonly observed in industrial wastewaters. Introduction of cyanide into industrial processes is usually by dissolution of potassium cyanide (KCN) or sodium cyanide (NaCN) in process waters. However, hydrogen cyanide (HCN) formed when the above salts are dissolved in water, is probably the most acutely lethal compound.

The relationslhip of pH to hydrogen cyanide formation is very important. As pH is lowered to below 7, more than 99 percent of the cyanide is present as HCN and less than 1 percent as cyanide ions. Thus, at neutral pH, that of most living organisms, the more toxic form of cyanide prevails.

Cyanide ions combine with numerous heavy metal ions to form complexes. The complexes are in equilibrium with HCN. Thus, the stability of the metal-cyanide complex and the pH determine the concentration of HCN. Stability of the metal-cyanide anion complexes is extremely variable. Those formed with zinc, copper, and cadmium are not stable - they rapidly dissociate, with production of HCN, in near neutral or acid waters. Some of the complexes are extremely stable. Cobaltocyanide is very resistant to acid distillation in the laboratory. Iron cyanide complexes are also stable, but undergo photodecomposition to give HCN upon exposure to sunlight. Synergistic effects have been demonstrated for the metal cyanide complexes making zinc, copper, and cadmium, cyanides more toxic than an equal concentration of sodium cyanide.

The toxic mechanism of cyanide is essentially an inhibition of oxygen metabolism, i.e., rendering the tissues incapable of exchanging oxygen. The cyanogen compounds are true noncummulative protoplasmic poisons. They arrest the activity of all forms of animal life. Cyanide shows a very specific type of toxic action. It inhibits the cytochrome oxidase system. This system is the one which facilitates electron transfer from reduced metabolites to molecular oxygen. The human body can convert cyanide to a non-toxic thiocyanate and eliminate it. However, if the quantity of cyanide ingested is too

great at one time, the inhibition of oxygen utilization proves fatal before the detoxifying reaction reduces the cyanide concentration to a safe level.

Cyanides are more toxic to fish than to lower forms of aquatic organisms such as midge larvae, crustaceans, and mussels. Toxicity to fish is a function of chemical form and concentration, and is influenced by the rate of metabolism (temperature), the level of dissolved oxygen, and pH. In laboratory studies free cyanide concentrations ranging from 0.05 to 0.15 mg/l have been proven to be fatal to sensitive fish species including trout, bluegill, and fathead minnows. Levels above 0.2 mg/l are rapidly fatal to most fish species. Long term sublethal concentrations of cyanide as low as 0.01 mg/l have been shown to affect the ability of fish to function normally, e.g., reproduce, grow, and swim.

For the protection of human health from the toxic properties of cyanide ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.200 mg/l.

Persistance of cyanide in water is highly variable and depends upon the chemical form of cyanide in the water, the concentration of cyanide, and the nature of other constituents. Cyanide may be destroyed by strong oxidizing agents such as permanganate and chlorine. Chlorine is commonly used to oxidize strong cyanide solutions. Carbon dioxide and nitrogen are the products of complete oxidation. But if the reaction is not complete, the very toxic compound, cyanogen chloride, may remain in the treatment system and subsequently be released to the environment. Partial chlorination may occur as part of a POTW treatment, or during the disinfection treatment of surface water for drinking water preparation.

Cyanides can interfere with treatment processes in POTW, or pass through to ambient waters. At low concentrations and with acclimated microflora, cyanide may be decomposed by microorganisms in anaerobic and aerobic environments or waste treatment systems. However, data indicate that much of the cyanide introduced passes through to the POTW effluent. The mean pass-through of 14 biological plants was 71 percent. In a recent study of 41 POTW the effluent concentrations ranged from 0.002 to 100 mg/l (mean = 2.518, standard deviation = 15.6). Cyanide also enhances the toxicity of metals commonly found in POTW effluents, including the priority pollutants cadmium, zinc, and copper.

Data for Grand Rapids, Michigan, showed a significant decline in cyanide concentrations downstream from the POTW after pretreatment regulations were put in force. Concentrations fell from 0.66 mg/l before, to 0.01 mg/l after pretreatment was required.

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Lead (122). Lead is a soft, malleable ductible, blueish-gray, metallic element, usually obtained from the mineral galena (lead sulfide, PbS), anglesite (lead sulfate, $PbSO_4$), or cerussite (lead carbonate, $PbCO_3$). Because it is usually associated with minerals of zinc, silver, copper, gold, cadmium, antimony, and arsenic, special purification methods are frequently used before and after extraction of the metal from the ore concentrate by smelting.

Lead is widely used for its corrosion resistance, sound and vibration absorption, low melting point (solders), and relatively high imperviousness to various forms of radiation. Small amounts of copper, antimony and other metals can be alloyed with lead to achieve greater hardness, stiffness, or corrosion resistance than is afforded by the pure metal. Lead compounds are used in glazes and paints. About one third of U.S. lead consumption goes into storage batteries. About half of U.S. lead consumption is from secondary lead recovery. U.S. consumption of lead is in the range of one million tons annually.

Lead ingested by humans produces a variety of toxic effects including impaired reproductive ability, disturbances in blood chemistry, neurological disorders, kidney damage, and adverse cardiovascular effects. Exposure to lead in the diet results in permanent increase in lead levels in the body. Most of the lead entering the body eventually becomes localized in the bones where it accumulates. Lead is a carcinogen or cocarcinogen in some species of experimental animals. Lead is teratogenic in experimental animals. Mutangenicity data are not available for lead.

For the protection of human health from the toxic properties of lead ingested through water and through contaminated aquatic organisms the ambient water criterion is 0.050 mg/l.

Lead is not destroyed in POTW, but is passed through to the effluent or retained in the POTW sludge; it can interfere with POTW treatment processes and can limit the usefulness of POTW sludge for application to agricultural croplands. Threshold concentration for inhibition of the activated sludge process is 0.1 mg/l, and for the nitrification process is 0.5 mg/l. In a study of 214 POTW, median pass through values were over 80 percent for primary plants and over 60 percent for trickling filter, activated sludge, and biological process plants. Lead concentration in POTW effluents ranged from 0.003 to 1.8 mg/l (means = 0.106 mg/l, standard deviation = 0.222).

Application of lead-containing sludge to cropland should not lead to uptake by crops under most conditions because normally lead is strongly bound by soil. However, under the unusual conditions of low pH (less than 5.5) and low concentrations of labile phosphorus, lead solubility is increased and plants can accumulate lead.

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Mercury. Mercury (123) is an elemental metal rarely found in nature
as the free metal.   Mercury is unique among metals as it remains a
liquid down to about 39 degrees below zero.   It is relatively inert
chemically and is insoluable in water.   The principal ore is cinnabar
(HgS).

Mercury is used industrially as the metal and as mercurous and
mercuric salts and compounds.   Mercury is used in several types of
batteries.   Mercury released to the aqueous environment is subject to
biomethylation - conversion to the extremely toxic methyl mercury.

Mercury can be introduced into the body through the skin and the
respiratory system as the elemental vapor.   Mercuric salts are highly
toxic to humans and can be absorbed through the gastrointestinal
tract.   Fatal doses can vary from 1 to 30 grams.   Chronic toxicity of
methyl mercury is evidenced primarily by neurological symptoms.   Some
mercuric salts cause death by kidney failure.

Mercuric salts are extremely toxic to fish and other aquatic life.
Mercuric chloride is more lethal than copper, hexavalent chromium,
zinc, nickel, and lead towards fish and aquatic life.   In the food
cycle, algae containing mercury up to 100 times the concentration in
the surrounding sea water are eaten by fish which further concentrate
the mercury.   Predators that eat the fish in turn concentrate the
mercury even further.

For the protection of human health from the toxic properties of
mercury ingested through water and through contaminated aquatic
organisms the ambient water criterion is determined to be 0.0002 mg/l.

Mercury is not destroyed when treated by a POTW, and will either pass
through to the POTW effluent or be incorporated into the POTW sludge.
At low concentrations it may reduce POTW removal efficiencies, and at
high concentrations it may upset the POTW operation.

The influent concentrations of mercury to POTW have been observed by
the EPA to range from 0.0002 to 0.24 mg/l, with a median concentration
of 0.001 mg/l.   Mercury has been reported in the literature to have
inhibiting effects upon an activated sludge POTW at levels as low as
0.1 mg/l.   At 5 mg/l of mercury, losses of COD removal efficiency of
14 to 40 percent have been reported, while at 10 mg/l loss of removal
of 59 percent has been reported.   Upset of an activated sludge POTW is
reported in the literature to occur near 200 mg/l.   The anaerobic
digestion process is much less affected by the presence of mercury,
with inhibitory effects being reported at 1365 mg/l.

In a study of 22 POTW having secondary treatment, the range of removal
of mercury from the influent to the POTW ranged from 4 to 99 percent

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with median removal of 41 percent. Thus significant pass through of mercury may occur.

In sludges, mercury content may be high if industrial sources of mercury contamination are present. Little is known about the form in which mercury occurs in sludge. Mercury may undergo biological methylation in sediments, but no methylation has been observed in soils, mud, or sewage sludge.

The mercury content of soils not receiving additions of POTW sewage sludge lie in the range from 0.01 to 0.5 mg/kg. In soils receiving POTW sludges for protracted periods, the concentration of mercury has been observed to approach 1.0 mg/kg. In the soil, mercury enters into reactions with the exchange complex of clay and organic fractions, forming both ionic and covalent bonds. Chemical and microbiological degradation of mercurials can take place side by side in the soil, and the products - ionic or molecular - are retained by organic matter and clay or may be volatilized if gaseous. Because of the high affinity between mercury and the solid soil surfaces, mercury persists in the upper layer of soil.

Mercury can enter plants through the roots, it can readily move to other parts of the plant, and it has been reported to cause injury to plants. In many plants mercury concentrations range from 0.01 to 0.20 mg/kg, but when plants are supplied with high levels of mercury, these concentrations can exceed 0.5 mg/kg. Bioconcentration occurs in animals ingesting mercury in food.

Nickel(124). Nickel is seldom found in nature as the pure elemental metal. 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. The chief commercial ores for nickel are pentlandite [$(Fe,Ni)_9S_8$], and a lateritic ore consisting of hydrated nickel-iron-magnesium silicate.

Nickel has many and varied uses. It is used in alloys and as the pure metal. Nickel salts are used for electroplating baths.

The toxicity of nickel to man is thought to be very low, and systemic poisoning of human beings by nickel or nickel salts is almost unknown. In non-human mammals nickel acts to inhibit insulin release, depress growth, and reduce cholesterol. A high incidence of cancer of the lung and nose has been reported in humans engaged in the refining of nickel.

Nickel salts can kill fish at very low concentrations. However, nickel has been found to be less toxic to some fish than copper, zinc, and iron. Nickel is present in coastal and open ocean water at concentrations in the range of 0.0001 to 0.006 mg/l although the most

common values are 0.002 - 0.003 mg/l. Marine animals contain up to 0.4 mg/l and marine plants contain up to 3 mg/l. Higher nickel concentrations have been reported to cause reduction in photosynthetic activity of the giant kelp. A low concentration was found to kill oyster eggs.

For the protection of human health based on the toxic properties of nickel ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.133 mg/l.

Nickel is not destroyed when treated in a POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge.   It can interfere with POTW treatment processes and can also limit the usefulness of municipal sludge.

Nickel salts have caused inhibition of the biochemical oxidation of sewage in a POTW.   In a pilot plant, slug doses of nickel significantly reduced normal treatment efficiencies for a few hours, but the plant acclimated itself somewhat to the slug dosage and appeared to achieve normal treatment efficiencies within 40 hours. It has been reported that the anaerobic digestion process is inhibited only by high concentrations of nickel, while a low concentration of nickel inhibits the nitrification process.

The influent concentration of nickel to POTW facilities has been observed by the EPA to range from 0.01 to 3.19 mg/l, with a median of 0.33 mg/l. In a study of 190 POTW, nickel pass-through was greater than 90 percent for 82 percent of the primary plants. Median pass-through for trickling filter, activated sludge, and biological process plants was greater than 80 percent.   POTW effuent concentrations ranged from   0.002   to   40 mg/l   (mean = 0.410,   standard deviation = 3.279).

Nickel not passed through the POTW will be incorporated into the sludge.   In a recent two-year study of eight cities, four of the cities had median nickel concentrations of over 350 mg/kg, and two were over 1,000 mg/kg. The maximum nickel concentration observed was 4,010 mg/kg.

Nickel is found in nearly all soils, plants, and waters. Nickel has no known essential function in plants. In soils, nickel typically is found in the range from 10 to 100 mg/kg. Various environmental exposures to nickel appear to correlate with increased incidence of tumors in man. For example, cancer in the maxillary antrum of snuff users may result from using plant material grown on soil high in nickel.

Nickel toxicity may develop in plants from application of sewage sludge on acid soils.   Nickel has caused reduction of yields for a

variety of crops including oats, mustard, turnips, and cabbage. In one study nickel decreased the yields of oats significantly at 100 mg/kg.

Whether nickel exerts a toxic effect on plants depends on several soil factors, the amount of nickel applied, and the contents of other metals in the sludge. Unlike copper and zinc, which are more available from inorganic sources than from sludge, nickel uptake by plants seems to be promoted by the presence of the organic matter in sludge. Soil treatments, such as liming reduce the solubility of nickel. Toxicity of nickel to plants is enhanced in acidic soils.

Selenium(125). Selenium (chemical symbol Se) is a non-metallic element existing in several allotropic forms. Gray selenium, which has a metallic appearance, is the stable form at ordinary temperatures and melts at 220°C. Selenium is a major component of 38 minerals and a minor component of 37 others found in various parts of the world. Most selenium is obtained as a by-product of precious metals recovery from electrolytic copper refinery slimes. U.S. annual production at one time reached one million pounds.

Principal uses of selenium are in semi-conductors, pigments, decoloring of glass, zerography, and metallurgy. It also is used to produce ruby glass used in signal lights. Several selenium compounds are important oxidizing agents in the synthesis of organic chemicals and drug products.

While results of some studies suggest that selenium may be an essential element in human nutrition, the toxic effects of selenium in humans are well established. Lassitude, loss of hair, discoloration and loss of fingernails are symptoms of selenium poisoning. In a fatal case of ingestion of a larger dose of selenium acid, peripheral vascular collapse, pulumonary edema, and coma occurred. Selenium produces mutagenic and teratogenic effects, but it has not been established as exhibiting carcinogenic activity.

For the protection of human health from the toxic properties of selenium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determind to be 0.010 mg/l.

Very few data are available regarding the behavior of selenium in POTW. One EPA survey of 103 POTW revealed one POTW using biological treatment and having selenium in the influent. Influent concentration was 0.0025 mg/l, effluent concentration was 0.0016 mg/l giving a removal of 37 percent. It is not known to be inhibitory to POTW processes. In another study, sludge from POTW in 16 cities was found to contain from 1.8 to 8.7 mg/kg selenium, compared to 0.01 to 2 mg/kg in untreated soil. These concentrations of selenium in sludge present

a potential hazard for humans or other mammuals eating crops grown on soil treated with selenium containing sludge.

Silver(126). Silver is a soft, lustrous, white metal that is insoluble in water and alkali. In nature, silver is found in the elemental state (native silver) and combined in ores such as argentite (Ag_2S), horn silver ($AgCl$), proustite (Ag_3AsS_3), and pyrargyrite (Ag_3SbS_3). Silver is used extensively in several industries, among them electroplating.

Metallic silver is not considered to be toxic, but most of its salts are toxic to a large number of organisms. Upon ingestion by humans, many silver salts are absorbed in the circulatory system and deposited in various body tissues, resulting in generalized or sometimes localized gray pigmentation of the skin and mucous membranes know as argyria. There is no known method for removing silver from the tissues once it is deposited, and the effect is cumulative.

Silver is recognized as a bactericide and doses from 0.000001 to 0.0005 mg/l have been reported as sufficient to sterilize water. The criterion for ambient water to protect human health from the toxic properties of silver ingested through water and through contaminated aquatic organisms is 0.010 mg/l.

The chronic toxic effects of silver on the aquatic environment have not been given as much attention as many other heavy metals. Data from existing literature support the fact that silver is very toxic to aquatic organisms. Despite the fact that silver is nearly the most toxic of the heavy metals, there are insufficient data to adequately evaluate even the effects of hardness on silver toxicity. There are no data available on the toxicity of different forms of silver.

There is no available literature on the incidental removal of silver by POTW. An incidental removal of about 50 percent is assumed as being representative. This is the highest average incidental removal of any metal for which data are available. (Copper has been indicated to have a median incidental removal rate of 49 percent).

Bioaccumulation and concentration of silver from sewage sludge has not been studied to any great degree. There is some indication that silver could be bioaccumulated in mushrooms to the extent that there could be adverse physiological effects on humans if they consumed large quantites of mushrooms grown in silver enriched soil. The effect, however, would tend to be unpleasant rather than fatal.

There is little summary data available on the quantity of silver discharged to POTW. Presumably there would be a tendency to limit its discharge from a manufacturing facility because of its high intrinsic value.

Zinc(128). Zinc occurs abundantly in the earth's crust, concentrated in ores. It is readily refined into the pure, stable, silvery-white metal. In addition to its use in alloys, zinc is used as a protective coating on steel. It is applied by hot dipping (i.e. dipping the steel in molten zinc) or by electroplating.

Zinc can have an adverse effect on man and animals at high concentrations. Zinc at concentrations in excess of 5 mg/l causes an undesirable taste which persists through conventional treatment. For the prevention of adverse effects due to these organoleptic properties of zinc, 5 mg/l was adopted for the ambient water criterion.

Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. Lethal concentrations in the range of 0.1 mg/l have been reported. Acutely toxic concentrations induce cellular breakdown of the gills, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc compounds cause general enfeeblement and widespread histological changes to many organs, but not to gills. Abnormal swimming behavior has been reported at 0.04 mg/l. Growth and maturation are retarded by zinc. It has been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated water may die as long as 48 hours after removal.

In general, salmonoids are most sensitive to elemental zinc in soft water; the rainbow trout is the most sensitive in hard waters. A complex relationship exists between zinc concentration, dissolved zinc concentration, pH, temperature, and calcium and magnesium concentration. Prediction of harmful effects has been less than reliable and controlled studies have not been extensively documented.

The major concern with zinc compounds in marine waters is not with acute lethal effects, but rather with the long-term sublethal effects of the metallic compounds and complexes. Zinc accumulates in some marine species, and marine animals contain zinc in the range of 6 to 1500 mg/kg. From the point of view of acute lethal effects, invertebrate marine animals seem to be the most sensitive organism tested.

Toxicities of zinc in nutrient solutions have been demonstrated for a number of plants. A variety of fresh water plants tested manifested harmful symptoms at concentrations of 10 mg/l. Zinc sulfate has also been found to be lethal to many plants and it could impair agricultural uses of the water.

Zinc is not destroyed when treated by POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with treatment processes in the POTW and can also limit the usefulness of municipal sludge.

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In slug doses, and particularly in the presence of copper, dissolved zinc can interfere with or seriously disrupt the operation of POTW 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.

The influent concentrations of zinc to POTW facilities has been observed by the EPA to range from 0.017 to 3.91 mg/l, with a median concentration of 0.33 mg/l. Primary treatment is not efficient in removing zinc; however, the microbial floc of secondary treatment readily adsorbs zinc.

In a study of 258 POTW, the median pass-through values were 70 to 88 percent for primary plants, 50 to 60 percent for trickling filter and biological process plants, and 30-40 percent for activated process plants. POTW effluent concentrations of zinc ranged from 0.003 to 3.6 mg/l (mean = 0.330, standard deviation = 0.464).

The zinc which does not pass through the POTW is retained in the sludge. The presence of zinc in sludge may limit its use on cropland. Sewage sludge contains 72 to over 30,000 mg/kg of zinc, with 3,366 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which range from 0 to 195 mg/kg, with 94 mg/kg being a common level. Therefore, application of sewage sludge to soil will generally increase the concentration of zinc in the soil. Zinc can be toxic to plants, depending upon soil pH. Lettuce, tomatoes, turnips, mustard, kale, and beets are especially sensitive to zinc contamination.

Aluminum. Aluminum is a non-conventional pollutant. It is a silvery white metal, very abundant in the earths crust (8.1 percent), but never found free in nature. Its principal ore is bauxite. Alumina (Al_2O_3) is extracted from the bauxite and dissolved in molten cryolite. Aluminum is produced by electrolysis of this melt.

Aluminum is light, malleable, ductile, possesses high thermal and electrical conductivity, and is non-magnetic. It can be formed, machined or cast. Although aluminum is very reactive, it forms a protective oxide film on the surface which prevents corrosion under many conditions. In contact with other metals in presence of moisture the protective film is destroyed and voluminous white corrosion products form. Strong acids and strong alkali also break down the protective film.

Aluminum is non-toxic and its salts are used as coagulants in water treatment. Although some aluminum salts are soluble, alkaline conditions cause precipitation of the aluminum as a hydroxide.

Aluminum is commonly used in cooking utensils. There are no reported adverse physiological effects on man from low concentrations of aluminum in drinking water.

Aluminum does not have any adverse effects on POTW operation at any concentrations normally encountered.

Ammonia.   Ammonia (chemical formula NH_3) is a non-conventional pollutant.   It is a colorless gas with a very pungent odor, detectable at concentrations of 20 ppm in air by the nose, and is very soluble in water (570 gm/l at 25°C).   Ammonia is produced industrially in very large quantities (nearly 20 millions tons annually in the U.S.).   It is converted to ammonium compounds or shipped in the liquid form (it liquifies at -33°C).   Ammonia also results from natural processes. Bacterial action on nitrates or nitrites, as well as dead plant and animal tissue and animal wastes produces ammonia.   Typical domestic wastewaters contain 12 to 50 mg/l ammonia.

The principal use of ammonia and its compounds is as fertilizer.   High amounts are introduced into soils and the water runoff from agricultural land by this use.   Smaller quantities of ammonia are used as a refrigerant.   Aqueous ammonia (2 to 5 percent solution) is widely used as a household cleaner.   Ammonium compounds find a variety of uses in various industries.

Ammonia is toxic to humans by inhalation of the gas or ingestion of aqueous solutions.   The ionized form (NH_4^+) is less toxic than the unionized form.   Ingestion of as little as one ounce of household ammonia has been reported as a fatal dose.   Whether inhaled or ingested, ammonia acts distructively on mucous membrane with resulting loss of function.   Aside from breaks in liquid ammonia refrigeration equipment, industrial hazard from ammonia exists where solutions of ammonium compounds may be accidently treated with a strong alkali, releasing ammonia gas.   As little as 150 ppm ammonia in air is reported to cause laryngeal spasm, and inhalation of 5000 ppm in air is considered sufficient to result in death.

The behavior of ammonia in POTW is well documented because it is a natural component of domestic wastewaters.   Only very high concentrations of ammonia compounds could overload POTW.   One study has shown that concentrations of unionized ammonia greater than 90 mg/l reduce gasification in anaerobic digesters and concentrations of 140 mg/l stop digestion competely. Corrosion of copper piping and excessive consumption of chlorine also result from high ammonia concentrations.   Interference with aerobic nitrification processes can occur when large concentrations of ammonia suppress dissolved oxygen. Nitrites are then produced instead of nitrates.   Elevated nitrite concentrations in drinking water are known to cause infant methemoglobinemia.

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Cobalt.   Cobalt is a non-conventional pollutant.   It is a brittle, hard, magnetic, gray metal with a reddish tinge.   Cobalt ores are usually the sulfide or arsenide [smaltite-$(Co,Ni)As_2$; cobaltite-CoAsS] and are sparingly distributed in the earth's crust.   Cobalt is usually produced as a by-product of mining copper, nickel, arsenic, iron, manganese, or silver. Because of the variety of ores and the very low concentrations of cobalt, recovery of the metal is accomplished by several different processes.   Most consumption of cobalt is for alloys. Over two-thirds of U.S. production goes to heat resistant, magnetic, and wear resistant alloys. Chemicals and color pigments make up most of the rest of consumption.

Cobalt and many of its alloys are not corrosion resistant,   therefore minor corrosion of any of the tool alloys or electrical resistance alloys can contribute to its presence in raw wastewater from a variety of manufacturing facilities. Additionally, the use of cobalt soaps as dryers to accelerate curing of unsaturated oils used in coatings may be a general source of small quantities of the metal. Several cobalt pigments are used in paints to produce yellows or blues.

Cobalt is an essential nutrient for humans and other mammals, and is present at a fairly constant level of about 1.2 mg in the adult human body. Mammals tolerate low levels of ingested water-soluble cobalt salts without any toxic symptoms; safe dosage levels in man have been stated to be 2-7 mg/kg body weight per day. A goitrogenic effect in humans is observed after the systemic administration of 3-4 mg cobalt as cobaltous chloride daily for three weeks.   Fatal heart disease among heavy beer drinkers was attributed to the cardiotoxic action of cobalt salts which were formerly used as additives to improve foaming. The carcinogenicity of cobalt in rats has been verified, however, there is no evidence for the involvement of dietary cobalt in carcinogenisis in mammals.

There are no data available on the behavior of cobalt in POTW.   There are no data to lead to an expectation of adverse effects of cobalt on POTW operation or the utility of sludge from POTW for crop application.   Cobalt which enters POTW is expected to pass through to the effluent unless sufficient sulfide ion is present, or generated in anaerobic processes in the POTW to cause precipitation of the very insoluble cobalt sulfide.

Iron.   Iron is a non-conventional polluant. It is an abundant metal found at many places in the earth's crust. The most common iron ore is hematite (Fe_2O_3) from which iron is obtained by reduction with carbon. Other forms of commercial ores are magnetite (Fe_3O_4) and taconite (FeSiO). Pure iron is not often found in commercial use, but it is usually alloyed with other metals and minerals. The most common of these is carbon.

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Iron is the basic element in the production of steel. 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.

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 ions 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 micro-nutrient for all forms of growth. Drinking water standards in the U.S. set a limit of 0.3 mg/l of iron in domestic water supplies based on aesthetic and organoleptic properties of iron in water.

High concentrations of iron do not pass through a POTW into the effluent. In some POTW iron salts are added to coagulate precipitates and suspended sediments into a sludge. In an EPA study of POTW the concentration of iron in the effluent of 22 biological POTW meeting secondary treatment performance levels ranged from 0.048 to 0.569 mg/l with a median value of 0.25 mg/l. This represented removals of 76 to 97 percent with a median of 87 percent removal.

Iron in sewage sludge spread on land used for agricultural purposes is not expcected to have a detrimental effect on crops grown on the land.

Manganese. Manganese is a non-conventional pollutant. It is a gray-white metal resembling iron, but more brittle. The pure metal does not occur in nature, but must be produced by reduction of the oxide with sodium, magnesium, or aluminum, or by electrolysis. The principal ores are pyrolusite (MnO_2) and psilomelane (a complex mixture of MnO_2 and oxides of potassium, barium and other alkali and alkaline earth metals). The largest percentage of manganese used in the U.S. is in ferro-manganese alloys. A small amount goes into dry batteries and chemicals.

Manganese is not often present in natural surface waters because its hydroxides and carbonates are only sparingly soluble.

Manganese is undesirable in domestic water supplies because it causes unpleasant tastes, deposits on food during cooking, stains and

discolors laundry and plumbing fixtures, and fosters the growth of some microorganisms in reservoirs, filters, and distribution systems.

Small concentratons of 0.2 to 0.3 mg/l manganese may cause building of heavy encrustations in piping. Excessive manganese is also undesirable in water for use in many industries, including textiles, dying, food processing, distilling, brewing, ice, and paper.

The recommended limitations for manganese in drinking water in the U.S. is 0.05 mg/l. The limit appears to be based on aesthetic and economic factors rather than physiological hazards. Most investigators regard manganese to be of no toxicological significance in drinking water at concentrations not causing unpleasant tastes. However, cases of manganese poisoning have been reported in the literature. A small outbreak of encephalitis - like disease, with early symptoms of lethergy and edema, was traced to manganese in the drinking water in a village near Tokyo. Three persons died as a result of poisoning by well water contaminated by manganese derived from dry-cell batteries buried nearby. Excess manganese in the drinking water is also believed to be the cause of a rare disease endemic in Northeastern China.

No data were found regarding the behavior of manganese in POTW. However, one source reports that typical mineral pickup from domestic water use results in an increase in manganese concentration of 0.2 to 0.4 mg/l in a municipal sewage system. Therefore, it is expected that interference in POTW, if it occurs, would not be noted until manganese concentrations exceeded 0.4 mg/l.

Phenols(Total). "Total Phenols" is a non-conventional pollutant parameter. Total phenols is the result of analysis using the 4-AAP (4-aminoantipyrene) method. This analytical procedure measures the color development of reaction products between 4-AAP and some phenols. The results are reported as phenol. Thus "total phenol" is not total phenols because many phenols (notably nitrophenols) do not react. Also, since each reacting phenol contributes to the color development to a different degree, and each phenol has a molecular weight different from others and from phenol itself, analyses of several mixtures containing the same total concentration in mg/l of several phenols will give different numbers depending on the proportions in the particular mixture.

Despite these limitations of the analytical method, total phenols is a useful parameter when the mix of phenols is relatively constant and an inexpensive monitoring method is desired. In any given plant or even in an industry subcategory, monitoring of "total phenols" provides an indication of the concentration of this group of priority pollutants as well as those phenols not selected as priority pollutants. A

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further advantage is that the method is widely used in water quality determinations.

In an EPA survey of 103 POTW the concentration of "total phenols" ranged grom 0.0001 mg/l to 0.176 mg/l in the influent, with a median concentration of 0.016 mg/l. Analysis of effluents from 22 of these same POTW which had biological treatment meeting secondary treatment performance levels showed "total phenols" concentrations ranging from 0 mg/l to 0.203 mg/l with a median of 0.007. Removals were 64 to 100 percent with a median of 78 percent.

It must be recognized, however, that six of the eleven priority pollutant phenols could be present in high concentrations and not be detected. Conversely, it is possible, but not probable, to have a high "total phenol" concentration without any phenol itself or any of the ten other priority pollutant phenols present. A characterization of the phenol mixture to be monitored to establish constancy of composition will allow "total phenols" to be used with confidence.

Strontium. Strontium, a non-conventional pollutant, is a hard silver-white alkaline earth metal. The metal reacts readily with water and moisture in the air. It does not occur as the free metal in nature. Principal ores are strontianite ($SrCO_3$) and celestite ($SrSO_4$). The metal is produced from the oxide by heating with aluminum, but no commerical uses for the pure metal are known.

Small percentages of strontium are alloyed with the lead used to cast grids for some maintenance free lead acid batteries. Strontium compounds are used in limited quantites in special applications. Strontium hydroxide [$Sr(OH)_2$] import thermal and mechanical stability and moisture resistance. The hydroxide is also used in preparation of stabilizers for vinyl plastics. Several strontium compounds are used in pyrotechnics.

Very few data are available regarding toxic effects of strontium in humans. Some studies indicate that strontium may be essential to growth in mammals. Large amounts of strontium compounds orally administered, have retarded growth and caused rickets in laboratory animals. Strontium is considered to be nontoxic or of very low toxicity in humans. Specific involvement of strontium toxicity in enzyme or biochemical systems is not known.

No reports were found regarding behavior of strontium in POTW. At the low concentrations of strontium to be expected under normal conditions, the strontium is expected to pass through into the POTW effluent in the dissolved state.

Oil and Grease. Oil and grease are taken together as one pollutant parameter. This is a conventional polluant and some of its components are:

1. 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 light hydrocarbons may make the removal of other heavier oil wastes more difficult.

2. Heavy Hydrocarbons, Fuels, and Tars - These include the crude oils, diesel oils, #6 fuel oil, residual oils, slop oils, and in some cases, asphalt and road tar.

3. 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.

4. Vegetable and Animal Fats and Oils - These originate primarily from processing of foods and natural products.

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 cause troublesome taste and odor problems. Scum lines from these agents are produced on water treatment basin walls and other containers. Fish and water fowl 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.

Many of the organic priority pollutants will be found distributed between the oily phase and the aqueous phase in industrial wastewaters. The presence of phenols, PCBs, PAHs, and almost any other organic pollutant in the oil and grease make characterization of this parameter almost impossible. However, all of these other organics add to the objectionable nature of the oil and grease.

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 fresh-water 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 show up as a sheen on the surface of a body of water. The presence of oil slicks decreases the aesthetic value of a waterway.

Oil and grease is compatible with a POTW activated sludge process in limited quantity. However, slug loadings or high concentrations of oil and grease interfere with biological treatment processes. The oils coat surfaces and solid particles, preventing access of oxygen, and sealing in some microorganisms. Land spreading of POTW sludge containing oil and grease uncontaminated by toxic pollutants is not expected to affect crops grown on the treated land, or animals eating those crops.

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 wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, suspended solids increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Supended solids in water interfere with many industrial processes and cause foaming in boilers and incrustastions on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing, and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in the water. Solids, when transformed to sludge deposit, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and

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maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Total suspended solids is a traditional pollutant which is compatible with a well-run POTW. This pollutant with the exception of those components which are described elsewhere in this section, e.g., heavy metal components, does not interfere with the operation of a POTW. However, since a considerable portion of the innocuous TSS may be inseparably bound to the constituents which do interfere with POTW operation, or produce unusable sludge, or subsequently dissolve to produce unacceptable POTW effluent, TSS may be considered a toxic waste hazard.

pH. Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not, however, a measure of either. The term pH is used to describe the hydrogen ion concentration (or activity) present in a given solution. Values for pH range from 0 to 14, and these numbers are the negative logarithms of the hydrogen ion concentrations. A pH of 7 indicates neutrality. Solutions with a pH above 7 are alkaline, while those solutions with a pH below 7 are acidic. The relationship of pH and acidity and alkalinity is not necessarily linear or direct. Knowledge of the water pH is useful in determining necessary measures for corroison control, sanitation, and disinfection. Its value is also necessary in the treatment of industrial wastewaters to determine amounts of chemcials required to remove pollutants and to measure their effectiveness. Removal of pollutants, especially dissolved solids is affected by the pH of the wastewater.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add constituents to drinking water such as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the taste of the water and at a low pH, water tastes sour. The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7.0. This is significant for providng safe drinking water.

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, metallocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units.

Because of the universal nature of pH and its effect on water quality and treatment, it is selected as a pollutant parameter for many

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industry categories. A neutral pH range (approximately 6-9) is generally desired because either extreme beyond this range has a deleterious effect on receiving waters or the pollutant nature of other wastewater constituents.

Pretreatment for regulation of pH is covered by the "General Pretreatment Regulations for Exisiting and New Sources of Pollution," 40 CFR 403.5. This section prohibits the discharge to a POTW of "pollutants which will cause corrosive structural damage to the POTW but in no case discharges with pH lower than 5.0 unless the works is specially designed to accommodate such discharges."

REGULATION OF SPECIFIC POLLUTANTS

For all subcategories except for the lead subcategory, discussion of individual pollutant parameters selected or not selected for consideration for specific regulation are based on concentrations obtained from sampling analysis of total raw wastewater streams for each battery manufacturing element. Depending on the specific element, only one or many manufacturing wastewater streams may be included in the total raw wastewater stream. Section V addressed each element, the samples collected, and analysis of these samples. Tables from the section are referenced where appropriate within each subcategory.

Cadmium Subcategory

Pollutant Parameters Selected for Regulation. Based on verification sampling results of the manufacturing elements and wastewater sources listed in Figure V-2 (Page 193), and a careful examination of the cadmium subcategory manufacturing processes and raw materials, twelve pollutant parameters were selected to be considered for regulation in effluent limitations and standards for this subcategory. The twelve are: cadmium, chromium, cyanide, lead, mercury, nickel, silver, zinc, cobalt, oil and grease, total suspended solids, and pH. These pollutants were observed at significant levels in raw wastewater produced in this subcategory and are amenable to control by identified wastewater treatment and control practices.

Cadmium concentrations appeared in 29 of 31 raw wastewater streams in the cadmium subcategory Since it is a cell reactant in cadmium anodes, it is involved in almost every step of the manufacturing process. The maximum cadmium concentration was 365 mg/l. Cadmium was present at levels that can be reduced by specific treatment methods. Therefore cadmium is considered for specific regulation.

Chromium concentrations appeared in 21 of 31 raw wastewater streams in the subcategory. The maximum concentration was 1.52 mg/l. Chromium is removed by specific treatment methods to levels less than some of

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the observed levels. Therefore chromium is considered for specific regulation.

Cyanide was found in 23 of 27 raw wastewater streams in the cadmium subcategory. The maximum concentration was 9.45 mg/l. Cyanide concentrations can be lowered by available specific treatment methods, and is therefore considered for regulation.

Lead concentrations appeared in 6 of 31 raw wastewater streams in the cadmium subcategory with appreciable levels (greater than 0.1 mg/l) observed from silver powder production. Since the maximum concentration of 0.281 mg/l can be reduced by specific treatment methods, lead is considered for specific regulation.

Mercury concentrations appeared in 15 of 31 raw wastewater streams in the cadmium subcategory. The maximum concentration was 0.032 mg/l. This priority pollutant is not an identified raw material in this subcategory. Mercury can be removed to lower concentrations by use of specific treatment methods. Accordingly, mercury is considered for specific regulation.

Nickel concentrations appeared in 30 of 31 raw wastewater streams in the cadmium subcategory. Since it is a cathode reactant and an electrode support material in cadmium anodes, nickel is involved in almost every step of the manufacturing process. The maximum nickel concentration in raw wastewater was 514 mg/l. Nickel can be removed by specific treatment methods and therefore is considered for specific regulation.

Silver concentrations appeared in 4 of 4 raw wastewater streams in the cadmium subcategory. All quantifiable concentrations were from silver powder production where the maximum concentration was 24.1 mg/l. Silver can be removed by specific treatment methods and is therefore considered for specific regulation in this subcategory.

Zinc concentrations appeared in 28 of 31 raw wastewater streams in the cadmium subcategory. The maximum zinc concentration in raw wastewater was 6,430 mg/l - in the stream from cadmium powder production. Other streams had concentrations of less than 13 mg/l. Zinc can be removed by specific treatment methods to concentrations lower than those measured in the raw wastewaters. Therefore zinc is considered for specific regulation.

Cobalt concentrations appeared in the raw wastewater in 13 of 31 streams in the cadmium subcategory. Cobalt is added to some nickel electrodes used in this subcategory. The maximum concentration was 5 mg/l. Because of its potentially toxic effect, and the fact that cobalt can be removed by specific treatment methods, cobalt is considered for specific regulation in this subcategory.

Oil and grease, a conventional pollutant, appeared at concentrations of up to 1960 mg/l in raw wastewater streams from all process elements in the cadmium subcategory. This pollutant can be removed by conventional treatment methods, and is therefore considered for regulation. Because it is present at raw waste concentrations greater than the 100 mg/l level considered acceptable for introduction into a POTW, it is considered for regulation for both indirect and direct discharges.

Suspended solids concentrations appeared in 27 of 30 raw wastewater streams from the cadmium subcategory analyzed for TSS. The maximum concentration was 2687 mg/l. Some of the TSS is comprised of hydroxides of cadmium, nickel or zinc. Because this conventional pollutant contains quantities of toxic metals, TSS requires consideration for regulation, both direct and indirect discharges from this subcategory.

The pH of wastewater streams resulting from the manufacture of cadmium anode batteries is observed to range from 1 to 14. Acid discharges may be associated with electrodeposition, impregnation, and metal recovery processes, and with the manufacture of cadmium powder. Highly alkaline wastewaters result from electrolyte losses and from rinses following precipitation of impregnated cadmium or nickel. Since deleterious environmental effects may result from pH values outside the range of 7.5 to 10.0, regulation of this parameter in the cadmium subcategory effluents is clearly required. Further, pH must be controlled for effective removal of other pollutants present in these effluents.

Pollutant Parameters Not Selected for Specific Regulation. Four pollutant parameters – methylene chloride, trichloroethylene, ammonia, and total phenols – were included in verification sampling and analysis, but were dropped from consideration for regulation in this subcategory after careful examination of concentration levels and manufacturing materials and processes.

Methylene chloride concentrations appeared in 6 of 30 raw wastewater streams from the cadmium subcategory. All values were below the quantifiable limit. Specific regulation of methylene chloride is not considered further.

Trichloroethylene concentrations appeared in 12 of the 30 raw wastewater streams from the cadmium subcategory. All values were below the quantifiable limit, therefore, specific regulation of trichloroethylene is not considered.

Ammonia concentrations appeared in 19 of 25 raw wastewater streams on which analysis was performed for this pollutant parameter in the cadmium subcategory. The maximum concentration was 86 mg/l. Other

concentrations were significantly less, and were below the level achievable with available specific treatment methods. Most concentrations were in the range of ammonia concentrations found in typical domestic wastewater. Specific regulation of ammonia is therefore not considered.

"Total phenols" concentrations appeared in 24 of 27 raw wastewater streams analyzed. The maximum concentration was 0.086 mg/l. Some of the priority pollutant phenols as well as many phenols which are not priority pollutants contribute to "total phenols." Because concentrations found in this subcategory are below the levels for which practical specific treatment methods exist, and because some plant inlet water samples showed total phenols as high as 0.020 mg/l, specific regulation of "total phenols" is not considered.

Calcium Subcategory

Parameters Selected for Specific Regulation. To be determined after verification analysis completed.

Lead Subcategory

Parameters Selected for Specific Regulation. Analysis of pollutant parameters in the lead subcategory included an evaluation of concentration in total raw wastewater streams from five plants in the subcategory (Table V-36 Page 292), an evaluation of concentrations in samples of individual process element streams (Table V-40 Page 298), and an evaluation of the raw materials and the manufacturing processes employed. This analysis led to the selection of thirteen pollutant parameters considered for specific regulation. The parameters selected are: antimony, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, iron, oil and grease, total suspended solids and pH. Each has been found in raw wastewater from plants in this subcategory at levels that are amenable to treatment and monitoring.

Antimony concentrations appeared in 4 of 13 total raw wastewater streams from the lead subcategory. Antimony is used as an alloying element in the lead grids used to make battery plates, therefore, its presence is expected in raw wastewaters. The maximum concentration in the total raw wastewater was 0.19 mg/l and in the pasting raw wastewater samples was as high as 3.67 mg/l. Since some measured raw wastewater concentrations are above the level which can be achieved by specific treatment methods, antimony is considered for specific regulation in this subcategory.

Cadmium concentration appeared in 10 of 13 total raw wasterwater streams from the lead subcategory. The maximum concentration was 0.03 mg/l in the total raw wastewater streams and as high as 0.34 mg/l in the battery repair raw wastewater samples. Since some of the

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measured concentrations in raw wastewaters are above the concentration level which can be achieve by specific treatment methods, cadmium is considered for specific regulation in this subcategory.

Chromium concentrations appeared in 12 of 12 total raw wastewater streams in the lead subcategory. The maximum concentration was 3.27 mg/l in the total raw wastewater streams and as high as 3.67 mg/l in the battery wash raw wastewater samples. Specific treatment methods can reduce chromium below this level. Therefore, chromium is considered for specific regulation.

Copper concentrations appeard in 12 of 12 total raw wastewater streams and individual process raw wastewater samples from the lead subcategory. The maximum concentration in the total raw wastewater streams was 2.50 mg/l, and as high as 9.85 mg/l in the battery repair raw wastewater samples. Copper is used for electrical conductors in charging operations and may be present in process equipment. It was not a primary raw material in the sampled plants but may be introduced into wastewaters by corrosion of equipment. All of the total raw wastewater copper concentrations are greater than the levels which can be achieved by specific treatment methods. Therefore, copper is considered for specific regulation in this subcategory.

Lead concentrations appeared in all total raw wastewater streams and individual process raw wastewater samples from the five plants in the lead subcategory. The maximum concentration was 45.9 mg/l in the total raw wastewater streams and as high as 6000 mg/l in the pasting raw wastewater samples. All concentrations were above the level which can be achieved by specific treatment methods. Therefore, lead is considered for specific regulation in this subcategory.

Mercury concentrations appeared in 4 of 12 total raw wastewater streams from the lead subcategory. Streams from only two plants contained this pollutant. The maximum concentration was 0.065 mg/l which was from the battery wash raw wastewater sample. Specific treatment methods remove mercury to levels lower than some of those found in these samples. Therefore, even though mercury is not a primary raw material or a process addition, specific regulation of mercury is considered in this subcategory.

Nickel concentrations appeared in 10 of 12 total raw wastewater streams in the lead subcategory. The maximum concentration was 2.8 mg/l which appeared in the battery wash raw wastewater samples and a maximum of 2.49 mg/l was in the total raw wastewater streams. Some of the concentrations were greater than the level which can be achieved with specific treatment methods. Therefore, although nickel is not a primary raw material, and is not a recognizable addition of any process step, this priority pollutant parameter is considered for specific regulation in this subcategory.

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Silver concentrations appeared in 8 of 13 total raw wastewater streams in the lead subcategory. The maximum concentration found was 0.03 mg/l in the total wastewater streams and as high as .71 mg/l in the pasting raw wastewater samples. Silver can be removed to concentrations below those found in some samples. Silver is not a primary raw material, but may be present in trace quantities in the lead used for grid in this subcategory. Silver is considered for specific regulation in this subcategory.

Zinc concentrations appeared in all total raw wastewater streams from the five plants in the lead subcategory. The maximum concentration was 6.8 mg/l in the total raw wastewater streams and as high as 9.87 mg/l in the battery repair raw wastewater samples. Many concentrations are above the level achievable with specific treatment methods. Thus, even though zinc is not a primary raw material in this subcategory, it is considered for specific regulation in this subcategory.

Iron concentrations appeared in all total raw wastewater streams that were analyzed for iron in the lead subcategory. The maximum iron concentration was 390 mg/l in the total raw wastewater streams and all concentrations were above 1 mg/l. Concentrations were as high as 460 mg/l in the battery repair raw wastewater samples. Iron in these raw wastewater streams is attributable to corrosion of process equipment and charging racks by sulfuric acid. The levels of iron in most of the sampled raw wastewater streams may produce undesirable environmental effects. The concentrations were greater than those which can be achieved by specific treatment methods. Therefore, iron is considered for specific regulation.

Oil and grease concentrations appeared in all raw wastewater streams and samples of the lead subcategory. Concentrations were as high as 49.0 mg/l in the total raw waste streams and as high as 1620 mg/l in the pasting process raw wastewater samples. This pollutant can be removed by conventional treatment methods. Therefore oil and grease is ·considered for specific regulation in this subcategory.

Suspended solids appeared in all streams at concentrations as high as 1300 mg/l in total raw wastewater streams at plants within the lead subcategory. TSS (Total Suspended Solids) may be introduced into wastewater at numerous points in the process, most notably in electrode grid pasting processes where concentrations were as high as 42,300 mg/l, and are also produced by the treatment of wastewater for · precipitation of metal pollutants. The TSS generated in this subcategory consists of large proportions of priority pollutants and is treatable. Therefore TSS is considered for specific regulation.

Raw waste streams in the lead subcategory are predominantly acidic because of contamination by sulfuric acid which is used as electrolyte

and in process steps. The pH of these wastewater samples range from 12 down to 1.8. Regulation of pH is considered in this subcategory to maintain the pH within the 7.5 to 10.0 range.

Parameters Not Selected for Specific Regulation. A total of fifteen pollutant parameters which were evaluated in verification analysis were dropped from further consideration for specific regulation in the lead subcategory. These parameters were found to be present in raw wastewaters infrequently, or at concentration below those usually achieved by specific treatment methods. The fifteen are: 1,1,1-trichloroethane, chloroform, methylene chloride, napththalene, phenol, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, di-n-butyl phthalate, di-n-octyl phthalate, anthracene, phenanthrene, pyrene, arsenic, strontium, and "total phenols."

1,1,1-Trichloroethane concentrations appeared in all of the total raw wastewater streams from plants in the lead subcategory. This priority pollutant is an industrial solvent and degreasing agent which might easily be present in any manufacturing plant. The maximum concentration was 0.025 mg/l, which is below the level considered achievable by available specific treatment methods. Therefore 1,1,1-trichloroethane is not considered for specific regulation in this subcategory.

Chloroform concentrations appeared in 6 of 13 total raw wastewater streams in the lead subcategory. The maximum concentration was 0.009 mg/l. Chloroform is not a specific raw material nor is it part of a process in this subcategory. Specific treatment methods do not bring chloroform concentrations down to the levels found in the raw wastewater. Therefore, chloroform is not considered for specific regulation in this subcategory.

Methylene chloride concentrations appeared 8 of 13 total raw wastewater streams in the lead subcategory. All concentrations were below the quantifiable limit for organic priority pollutants. Therefore methylene chloride is not considered for specific regulation in this subcategory.

Naphthalene concentrations appeared in 10 of 13 total raw wastewater streams from the lead subcategory. The maximum concentration was 0.01 mg/l in the total raw wastewater streams and as high as 0.037 mg/l in the battery wash raw wastewater samples. This priority pollutant is not a raw material nor is it part of a process. Concentrations were below the level considered to be achievable with available specific treatment methods. Therefore, naphthalene is not considered for specific regulation in this subcategory.

Phenol concentrations appeared in only one of three total raw wastewater streams from the lead subcategory which were subjected to

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analysis for this priority pollutant. The concentration is below the quantifiable limit. Therefore, phenol is not considered for specific regulation.

Four priority pollutant phthalate ester streams concentrations appeared in total raw wastewater streams from the lead subcategory. Bis (2-ethylhexyl) phthalate concentrations appeared in all total raw wastewater streams at concentrations up to 0.135 mg/l. The other four esters - butyl benzyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate were present in fewer samples and, with the exception of di-n-octyl phthalate which had a maximum of 0.14 mg/l, were found at lower concentrations. None of these esters are raw materials, nor are they part of processes. All these esters are used as plasticizers which would result in their presence in the plant equipment and piping, and some have additional uses such as denaturant for alcohol in personal care items. Therefore, even though specific treatment methods can achieve lower concentrations than some which were found, specific regulation of these four phthalate esters in the lead subcategory is not considered.

Three PAH - anthracene, phenanthrene, and pyrene concentrations appeared in total raw wastewater streams analyzed for these priority pollutant parameters. The maximum concentration was 0.032 mg/l for anthracene and phenanthrene and all other values were below the quantifiable limit, where only detections are recorded. None of these compounds are used in processes or as raw materials in the lead subcategory, and only the greatest concentration measured is above the level which is considered to be achievable by available specific treatment methods. Therefore, none of these three PAH are considered for specific regulation in this subcategory.

Arsenic concentrations appeared in 4 of 12 total raw wastewater streams from the lead subcategory. In the total raw wastewater streams the maximum concentration was 0.12 mg/l and as high as 0.13 mg/l in a battery wash raw waster sample. Only two of the five plants sampled had arsenic in the raw wastewater. Arsenic is an additive of lead used in some battery plate grids. However, concentration levels attainable by specific treatment methods are several times higher than the maximum reported raw wastewater concentration. Therefore, arsenic is not considered for specific regulation in this subcategory.

Strontium concentrations appeared in 5 of 12 total raw wastewater streams analyzed for this pollutant parameter. Streams from three of the five plants sampled in the lead subcategory contained strontium. The maximum concentration of 0.039 mg/l which appeared in the battery wash raw wastewater samples is lower than the level that can be achieved by available specific treatment methods. Therefore,

strontium is not considered for specific regulation in this subcategory.

"Total phenols" concentrations appeared in 8 of 13 total raw wastewater streams analyzed for this pollutant parameter in the lead subcategory. The maximum concentration appeared in the battery repair raw wastewater samples and was 0.174 mg/l. Concentrations ranged from 0.01 mg/l to 0.05 mg/l in the total raw wastewater streams which are below those for which practical specific treatment methods exist. Some phenols will be removed with oil and grease removal treatments. Therefore, specific regulation of "total phenols" is not considered in this subcategory.

Leclanche Subcategory

Pollutant Parameters Selected for Specific Regulation. The analysis of raw wastewater samples from the manufacturing elements (including the screening sample) and wastewater sources listed in Figure V-19 (Page 211), and an evaluation of raw materials and manufacturing processes employed led to the selection of thirteen pollutant parameters for consideration for specific regulation. The parameters selected are: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc, manganese, oil and grease, total suspended solids and pH. Each has been found in raw wastewaters from plants in this subcategory at levels that are amenable to treatment and monitoring.

Arsenic concentrations appeared 3 of 13 raw wastewater streams in the Leclanche subcategory. All concentrations appeared in ancillary operations from one plant on three sampling days. The concentration ranged from 0.07 mg/l to 0.64 mg/l. Arsenic has been determined to have carcinogenic properties, and specific treatment methods for removal of arsenic at the observed concentrations are available. Therefore, arsenic is considered for specific regulation.

Cadmium concentrations appeared in all 13 raw wastewater streams from the Leclanche subcategory. The maximum concentration was 0.47 mg/l. Cadmium is a toxic metal and can be removed by specific treatment methods to concentrations below those found in most of the raw wastewater streams. Therefore, cadmium is considered for specific regulation.

Total chromium concentrations appeared in 7 of 13 raw wastewater streams from the Leclanche subcategory. The maximum concentration was 2.88 mg/l. Chromium is a toxic metal which can be removed by specific treatment methods. Therefore, it is considered for specific regulation.

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Copper concentrations appeared in all 13 raw wastewater streams from the Leclanche subcategory at concentrations up to 3.22 mg/l. Copper is not introduced as a raw material or as part of a process. However, all concentrations are above the level which can be achieved by specific treatment methods. Therefore, copper is considered for specific regulation in this subcategory.

Lead concentrations appeared in 4 of 13 raw wastewater streams sampled, and also from one analysis supplied by one plant in the Leclanche subcategory. The concentrations ranged from 0.07 mg/l to 0.94 mg/l (verification sample) and the maximum concentration was 6.0 mg/l (screening sample). All concentrations were greater than the levels which can be obtained with specific treatment methods for lead removal. Therefore, even though lead is not a raw material and is not introducted by an identified process in this subcategory it is considered for specific regulation.

Mercury concentrations appeared in 10 of 12 sampled raw wastewater streams in the Leclanche subcategory and concentrations were also reported from dcp information for three plants. The maximum concentration was 6.0 mg/l from the sampling data and 117 mg/l from dcp data. Mercury is a toxic metal used as a raw material in this subcategory. It can be removed from wastewaters by specific treatment methods at the concentrations found. Mercury is considered for specific regulation.

Nickel concentrations appeared in all 13 sampled raw wastewater streams in the Leclanche subcategory and, also one chemical analysis was supplied by one plant. The maximum concentration was 10.1 mg/l. Nickel is a toxic metal and can be removed by specific treatment methods. Therefore, nickel is considered for specific regulation.

Selenium concentrations appeared in the same 3 out of 13 raw wastewater streams in which arsenic was found in the Leclanche subcategory. The concentration range was 0.07 mg/l to 0.6 mg/l. Although selenium is not a recognized component of any of the raw materials used in this subcategory, it was reported as present in one plant's wastewater by dcp information. Because of its toxic nature and the fact that specific treatment methods can remove this pollutant parameter, selenium is considered for specific regulation.

Zinc concentrations appeared in all raw wastewater streams analyzed for zinc in the Leclanche subcategory, and also from two chemical analyses supplied by two plants. The maximum concentration from sampling was 2000 mg/l (screening) and 1640 mg/l from plant data. Zinc is a major raw material for this subcategory and can be removed by specific treatment methods. Therefore, this priority pollutant is considered for specific regulation.

Manganese concentrations appeared in all raw wastewater samples in the Leclanche subcategory. The maximum concentration was 383 mg/l, and six concentrations were 10 mg/l or greater. Manganese dioxide is a raw material for this subcategory and is generally regarded as undesirable in water used for various processes as well as for drinking water. Manganese can be removed by specific treatment methods. Therefore, manganese is considered for specific regulation.

The oil and grease parameter concentrations appeared in all raw wastewater streams, but the screening raw wastewater streams in the Leclanche subcategory. The maximum concentration was 482 mg/l and in one other sample a concentration of 438 mg/l was found. All other concentrations were below 100 mg/l. Conventional methods can be used to remove oil and grease, therefore, this parameter is considered for specific regulation.

Suspended solids were present in process wastewater streams from the Leclanche subcategory at concentrations as high as 14,200 mg/l. Additional suspended solids will result from chemical treatment of these waste streams to precipitate metallic pollutants. Although TSS is a conventional pollutant, the TSS generated in this subcategory consists of large proportions of priority pollutants. Specific treatment methods remove TSS below the levels which were found in most samples. Therefore specific regulation of TSS must be considered in this subcategory.

The pH of wastewater streams from the Leclanche subcategory was observed to range between 5.1 and 10.4. Treatment of these waste streams for removal of toxic metals may require adjustment of the pH outside of the range acceptable for discharge to surface waters – pH 7.5 to 10. Therefore, pH requires specific regulation in process wastewater effluents from this subcategory.

Pollutant Parameters Not Selected for Specific Regulation.

Three pollutant parameters included in verification sampling and analysis – diethyl phthalate, antimony, and total phenols were not selected for specific regulation. These parameters were present infrequently, or at low concentrations, in raw wastewaters and are not directly attributable to processes or raw materials used in this subcategory.

Diethyl phthalate concentrations appeared in all raw wastewaters streams in the Leclanche subcategory, but the maximum concentration was only 0.016 mg/l. This priority pollutant is not a known component of any raw material or process used in this subcategory. Because of the widespread use of diethyl phthalate as a plasticizer, the compound is found in many components of plant equipment and piping as well as various consumer products used by employees. These are not process

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specific sources. The concentrations are below the levels that available specific treatment methods are expected to achieve. Therefore, diethyl phthalate is not considered for specific regulation.

Antimony concentrations appeared in only the screening raw wastewater stream in the Leclanche subcategory. It is not used or introduced in the raw materials of manufacturing process. Therefore, antimony is not considered for specific regulation.

The parameter designated "total phenols" had concentrations appearing in 11 of 11 raw wastewater streams in this subcategory. The maximum concentration was 14.9 mg/l. All other values ranged from 0.009 to 0.253 mg/l. Phenols are not used in any process or as a raw material in the Leclanche subcategory. However, the maximum value was from the single sample from a wet pasting operation for which phenolic compounds are commonly used as starch paste preservatives. This operation has been discontinued since sampling the plant. Although specific removal of phenols is possible, specific treatment is costly. Many phenols are removed with oil and grease. Therefore, total phenols is not considered for specific regulation.

Lithium Subcategory

Parameters Selected for Specific Regulation. To be determined after verification analysis completed.

Magnesium Subcategory

Parameters Selected for Specific Regulation. To be determined after verification analysis completed.

Zinc Subcategory

Parameters Selected for Regulation. Based on verification sampling results and a careful examination of the zinc subcategory manufacturing elements and wastewater sources listed in Figure V-25 (Page 217), manufacturing processes and raw materials, seventeen pollutant parameters were selected for consideration for specific regulation in effluent limitations and standards for this subcategory. The seventeen are: arsenic, cadmium, total chromium, copper, total cyanide, lead, mercury, nickel, selenium, silver, zinc, aluminum, iron, manganese, oil and grease, total suspended solids, and pH. These pollutants were found in raw wastewaters from this subcategory at levels that are amenable to control by specific treatment methods.

Arsenic concentrations appeared in 26 of 59 raw wastewater streams from the zinc subcategory. The maximum concentration was 5.9 mg/l. Ten values were greater than 1 mg/l. Arsenic is not a raw material

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and is not associated with any process used in the subcategory. The arsenic probably is a contaminant in one of the raw materials. Specific treatment methods achieve lower concentrations than were found in many samples, therefore, arsenic is considered for specific regulation.

Cadmium concentrations appeared in 50 of 70 raw wastewater streams from the zinc subcategory. The maximum concentrations were 79.2 mg/l from nickel impregnated cathodes, and 5.99 mg/l from silver peroxide raw wastewater streams. All other values were less than 0.2 mg/l. Cadmium can be removed by specific treatment methods to concentrations lower than those reported for many of the samples. Therefore, cadmium is considered for specific regulation.

Total chromium concentrations appeared in 56 of 70 raw wastewater streams from the zinc subcategory. Three samples from the cell wash operation at one plant contained 253 to 318 mg/l total chromium. Other raw wastewater streams ranged from 73.1 mg/l down to 0.002 mg/l. Many of the observed concentrations are greater than the level that can be achieved with specific treatment methods. Therefore, total chromium is considered for specific regulation.

Copper concentrations appeared in 48 of 58 raw wastewater streams from the zinc subcategory. Copper is used for electrode supports in cells. It is also used as an electrical conductor in process equipment. The maximum concentration was 10.5 mg/l. Copper can be removed by specific treatment methods to levels lower than many of the observed values. Therefore, copper is considered for specific regulation in the zinc subcategory.

Total cyanide concentrations appeared in 28 of 38 raw wastewater streams. The maximum concentrations were observed in the cell wash stream from one plant where the range was 2.1 to 7.2 mg/l. Most raw wastewater streams contained less than 0.1 mg/l. However, the wastewater streams contain levels that can be treated by specific methods to achieve lower concentrations. Therefore, cyanide is considered for specific regulation.

Lead concentrations appeared in 21 of 68 raw wastewater streams in the zinc subcategory. The maximum concentration was 0.82 mg/l. Although lead is not a raw material and is not part of a process, it was present in various raw wastewater streams at seven of the eight sampled plants in this subcategory. Lead can be removed by specific treatment methods to achieve lower concentrations than most of those found. Therefore, lead is considered for specific regulation in the zinc subcategory.

Mercury concentrations appeared in 45 of 57 raw wastewater samples from the zinc subcategory. This priority pollutant is used to

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amalgamate zinc anodes and therefore is expected in raw wastewaters. The maximum concentration was 30.78 mg/l. Specific treatment methods can achieve mercury concentrations lower than most of the reported raw wastewater values. Therefore, mercury is considered for specific regulation in this subcategory.

Nickel concentrations appeared in 46 of 70 raw wastewater streams from the zinc subcategory. Nickel is the primary raw material for impregnated nickel cathodes in this subcategory, but it also appeared in various raw wastewater streams from all plants sampled. The maximum concentrations were 514 mg/l from the nickel cathode streams and 24.4 mg/l from cell wash streams. Nickel is considered for regulation in the zinc subcategory.

Selenium concentrations appeared in 12 of 39 raw wastewater streams from the zinc subcategory. The measured concentrations ranged from 0.046 to 4.8 mg/l. Most concentrations are above the level which can be achieved by specific treatment methods. Selenium is not a raw material nor is it a process material in this subcategory. Its presence is probably associated with the use of silver or other raw material with a high selenium content. This priority pollutant is considered for specific regulation in the zinc subcategory.

Silver concentrations appeared in 42 of 60 raw wastewater streams in the zinc subcategory. Silver is the raw material for silver oxide cathodes used in some of the batteries in this subcategory. The maximum concentration was 71 mg/l. Silver can be removed by specific treatment methods to give concentrations lower than many of the reported values. Silver is considered for specific regulation in the zinc subcategory.

Zinc, is a principal raw material in the zinc subcategory. Zinc concentrations appeared in 67 of 69 raw wastewater streams. The two streams showing zero concentrations of zinc were from two streams for silver cathodes. Nearly half of the samples contained more than 10 mg/l zinc, and the maximum concentration was 1,100 mg/l. All of those concentrations are greater than those that can be achieved by specific treatment methods. Therefore, zinc is considered for specific regulation in this subcategory.

Aluminum concentrations appeared in 15 of 38 raw wastewater streams in the zinc subcategory. The maximum concentration was 106 mg/l from reject cell wastewater samples. Aluminum can be removed by specific treatment methods to levels less than those found in several of the samples. Therefore, aluminum is considered for specific regulation.

Iron concentrations appeared in two of two raw wastewater streams sampled. The maximum concentration was 0.57 mg/l. This concentration is treatable and iron is therefore considered for regulation.

Manganese concentrations appeared in 47 of 60 raw wastewater streams from the zinc subcategory. The maximum concentration was 69.6 mg/l. Manganese dioxide is a raw material for plants that make alkaline manganese cells in this subcategory. Some of the concentrations are above the level which can be achieved by specific treatment methods. Therefore, manganese is considered for specific regulation.

Phenols (total) concentrations appeared in 30 of 43 raw wastewater streams from the zinc subcategory. The maximum value was 0.12 mg/l in one raw wastewater stream. Several element streams and total plant raw wastewater streams contain treatable wastewaters, however, the concentrations detected are not environmentally significant, and only some of the concentrations detected are treatable. Therefore, total phenols is not considered for specific regulation.

Oil and grease concentrations appeared in 42 of 43 raw wastewater streams in the zinc subcategory. The maximum concentration was 205 mg/l, and half the samples contained more than 10 mg/l. Oil and grease can enter the raw wastewater from cell washing operations and from production machinery. Many oil and grease concentrations reported in this subcategory can be reduced by specific treatment methods. Some of the concentrations found are greater than are acceptable by POTW. Therefore, oil and grease are considered for specific regulation in this subcategory.

Suspended solids concentrations appeared in 66 of 68 raw wastewater samples in the zinc subcategory. The maximum concentration of total suspended solids (TSS) was 2,800 mg/l. About half the sample contained greater than 50 mg/l TSS. TSS consists of a variety of metal powders and oxides from raw materials and processes. In addition, TSS is generated by chemical precipitation methods used to remove some other pollutants. Specific treatment methods remove TSS to levels below those found in many samples. Therefore, TSS is considered for specific regulation in the zinc subcategory.

The pH of 43 raw wastewater samples in the zinc subcategory ranged from 1.0 to 13.5. Alkaline values predominated because the electrolytes in the cells in this subcategory are alkaline. Treatment of raw wastewaters for removal of other pollutant parameters can result in pH values outside the acceptable 7.5 to 10.0 range. Specific treatment methods can readily bring pH values within the prescribed limits. Therefore, pH is considered for specific regulation in the zinc subcategory.

Parameters Not Selected for Specific Regulation. Sixteen pollutant parameters which were evaluated in verification analysis were dropped from further consideration for specific regulation in the zinc subcategory. These parameters were found to be present in raw wastewaters infrequently, at levels considered to be not

environmentally significant, or at concentrations below those usually achieved by specific treatment methods. The sixteen were: 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethylene, 1,2-trans-dichloroethylene, ethylbenzene, methylene chloride, naphthalene, pentachlorophenol, bis(2-ethylhexyl) phthalate, diethyl phthalate, tetrachloroethylene, toluene, trichloroethylene, antimony, ammonia, and total phenols.

1,1,1-trichloroethane concentrations appeared in 22 of 57 raw wastewater streams analyzed for this priority pollutant parameter in the zinc subcategory. The maximum concentration was 0.025 mg/l. All but one other concentration were less than the quantifiable limit. Available specific treatment methods are not expected to remove 1,1,1-trichloroethane present in wastewater at this concentration. Therefore, this priority pollutant is not considered for specific regulation in this subcategory.

1,1-Dichloroethane concentrations appeared in 12 of 34 raw wastewater streams analyzed for this priority pollutant in the zinc subcategory. The maximum concentration was 0.03 mg/l. All other concentrations were less than the quantifiable limit. Available specific treatment methods are not expected to remove 1,1-dichloroethane present in wastewaters at this concentration. Therefore, this priority pollutant is not considered for specific regulation in this subcategory.

1,1-Dichloroethylene concentrations appeared in 12 of 36 raw wastewater streams analyzed for this priority pollutant in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, 1,1-dichloroethylene is not considered for specific regulation in this subcategory.

1,2-Trans-dichloroethylene concentrations appeared in only 4 of 36 raw wastewater streams in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, 1,2-trans-dichloroethylene is not considered for regulation in this subcategory.

Ethylbenzene was detected in only 2 of 32 raw wastewater samples in the zinc subcategory. The concentrations were below the quantifiable limit. Therefore, ethyl benzene is not considered for specific regulation in this subcategory.

Methylene chloride concentrations appeared in 18 of 67 raw wastewater streams in the zinc subcategory. The maximum concentration was 0.023 mg/l. All other concentrations were below the quantifiable limit. Available specific treatment methods are not expected to remove methylene chloride present in wastewater at the maximum concentration found. Therefore, methylene chloride is not considered for specific regulation in this subcategory.

Naphthalene concentrations appeared in 16 of 37 raw wastewater streams in the zinc subcategory. The maximum concentration was 0.02 mg/l. All concentrations were less than the quantifiable limit. Available treatment methods are not expected to remove napthalene present in the wastewater at the maximum concentration found. Therefore, naphthalene is not considered for specific regulation in this subcategory.

Pentachlorophenol concentrations appeared in 1 of 14 raw wastewater streams in the zinc subcategory. The concentration was 0.042 mg/l. Available specific treatment methods are considered capable of achieving lower concentrations of this priority pollutant than the observed value. However, because pentachlorophenol was detected only once,
                                        this priority pollutant is not considered for specific regulation in this subcategory.

Bis(2-ethylhexyl) phthalate concentrations appeared in all 21 raw wastewater streams analyzed for this priority pollutant. The maximum concentration was 0.161 mg/l. Available specific treatment methods are considered capable of achieving lower concentrations of this priority pollutant than many of those reported. This priority pollutant is not a raw material or process chemical and is found distributed widely in industrial environments as a plasticizer.

                         Therefore, bis(2-ethylhexyl) phthalate is not considered for specific regulation in this subcategory.

Diethyl phthalate concentrations appeared in 14 of 37 raw wastewater streams in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, diethyl phthalate is not considered for specific regulation in this subcategory.

Tetrachloroethylene concentrations appeared in 5 of 38 raw wastewater streams in the zinc subcategory. All of the concentrations were less than the quantifiable limit. Therefore, tetrachloroethylene is not considered for specific regulation in this subcategory.

Toluene concentrations appeared in 10 of 67 raw wastewater streams in the zinc subcategory. All concentrations were less than the quantifiable limit. Therefore, toluene is not considered for specific regulation in this subcategory.

Trichloroethylene was found in 17 of 51 raw wastewater samples in the zinc subcategory. The only value greater than the quantifiable limit was 0.012 mg/l. Available specific treatment methods are not expected to remove trichloroethylene present in raw wastewaters at the maximum concentration found. Therefore, trichloroethylene is not considered for regulation in this subcategory.

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Antimony concentrations did not appear in any of the 56 raw wastewater streams from the zinc subcategory. Antimony was included in verification sampling for this subcategory on the basis of dcp reports that antimony was present in the raw wastewaters. Antimony is not considered for specific regulation in this subcategory.

Ammonia concentrations appeared in 31 of 31 raw wastewater streams analyzed for this pollutant in the zinc subcategory. Maximum concentrations for each element stream ranged from 0.84 to 120 mg/l. The maximum concentration in total plant raw wastewater streams was 8.0 mg/l. Available specific treatment methods are not expected to remove ammonia present in total raw wastewaters at the maximum level found. Therefore, ammonia is not considered for specific regulation in this subcategory.

Summary

Tables VI-1, VI-3, VI-6, and VI-7 (Pages 449-476) present the selection of priority pollutant parameters for consideration for specific regulation for the cadmium, lead, leclanche and zinc subcategories, respectively. The selection is based on all sampling results. The "Not Detected" column includes pollutants which were not detected and not selected during screening analysis of total plant raw wastewater, and those that were selected at screening, but not detected during verification analysis of process raw wastewater streams within the subcategories. "Not Quantifiable" includes those pollutants which were at or below the quantifiable limits in influent, raw or effluent waters and not selected at screening, and those not quantifiable for all verification raw wastewater stream analysis within each subcategory. For screening samples, "Environmentally Insignificant" includes those samples which were detected at higher concentrations than the raw wastewater in the influent and effluent and not selected for verification. For verification analysis, "Environmentally Insignificant" includes parameters found in only one plant, present only below an environmentally significant level, or those that cannot be attributed to the point source category because they are generally found in plant equipment. "Not Treatable" means that concentrations were lower than the level achievable with the specific treatment methods considered in Section VII. Table VI-8 (Page 477) summarizes the selection of non-conventional and conventional pollutant parameters for consideration for specific regulation by subcategory.

TABLE VI-1
PRIORITY POLLUTANT DISPOSITION

Cadmium Subcategory

	POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001	Acenaphthene	X				
002	Acrolein	X				
003	Acrylonitrile	X				
004	Benzene		X			
005	Benzidine	X				
006	Carbon tetrachloride (tetrachloromethane)	X				
007	Chlorobenzene	X				
008	1,2,4-trichlorobenzene	X				
009	Hexachlorobenzene	X				
010	1,2-dichloroethane	X				
011	1,1,1-trichlorethane	X				
012	Hexachloroethane	X				
013	1,1-dichloroethane	X				
014	1,1,2-trichloroethane	X				
015	1,1,2,2-tetrachloroethane	X				
016	Chloroethane	X				
017	Bis (chloromethyl) ether	X				
018	Bis (2-chloroethyl) ether	X				
019	2-chloroethyl vinyl ether (mixed)	X				
020	2-chloronaphthalene	X				
021	2,4,6-trichlorophenol	X				
022	Parachlorometa cresol	X				
023	Chloroform (trichloro-methane)			X		
024	2-chlorophenol	X				
025	1,2-dichlorobenzene	X				
026	1,3-dichlorobenzene	X				
027	1,4-dichlorobenzene	X				
028	3,3-dichlorobenzidine	X				
029	1,1-dichloroethylene	X				
030	1,2-trans-dichloroethylene	X				
031	2,4-dichlorophenol	X				
032	1,2-dichloropropane	X				
033	1,2-dichloropropylene (1,3-dichloropropene)	X				

TABLE VI-1 Continued

034	2,4-dimethylphenol	X	
035	2,4-dinitrotoluene	X	
036	2,6-dinitrotoluene	X	
037	1,2-diphenylhydrazine	X	
038	Ethylbenzene	X	
039	Fluoranthene	X	
040	4-chlorophenyl phenyl ether	X	
041	4-bromophenyl phenyl ether	X	
042	Bis(2-chloroisopropyl) ether	X	
043	Bis(2-chloroethoxy) methane	X	
044	Methylene chloride (dichloromethane)		X
045	Methyl chloride (dichloromethane)	X	
046	Methyl bromide (bromomethane)	X	
047	Bromoform (tribromo-methane)	X	
048	Dichlorobromomethane		X
049	Trichlorofluoromethane	X	
050	Dichlorodifluoromethane	X	
051	Chlorodibromomethane	X	
052	Hexachlorobutadiene	X	
053	Hexachloromyclopenta-diene	X	
054	Isophorone	X	
055	Naphthalene	X	
056	Nitrobenzene	X	
057	2-nitrophenol	X	
058	4-nitrophenol	X	
059	2,4-dinitrophenol	X	
060	4,6-dinitro-o-cresol	X	
061	N-nitrosodimethylamine	X	
062	N-nitrosodiphenylamine	X	
063	N-nitrosodi-n-propylamine	X	
064	Pentachlorophenol	X	
065	Phenol	X	
066	Bis(2-ethylhexyl)phthalate		X
067	Butyl benzyl phthalate	X	
068	Di-N-Butyl Phthalate	X	
069	Di-n-octyl phthalate	X	
070	Diethyl Phthalate	X	
071	Dimethyl phthalate	X	
072	1,2-benzanthracene	X	

TABLE VI-1 Continued

	(benzo(a)anthracene)			
073	Benzo(a)pyrene (3,4-benzo-pyrene)	X		
074	3,4-Benzofluoranthene (benzo(b)fluoranthene)	X		
075	11,12-benzofluoranthene (benzo(b)fluoranthene)	X		
076	Chrysene	X		
077	Acenaphthylene	X		
078	Anthracene	X		
079	1,12-benzoperylene (benzo(ghi)perylene)	X		
080	Fluorene	X		
081	Phenanthrene	X		
082	1,2,5,6-dibenzanthracene (dibenzo(,h)anthracene)	X		
083	Indeno(1,2,3-cd) pyrene (2,3-o-pheynylene pyrene)	X		
084	Pyrene	X		
085	Tetrachloroethylene	X		
086	Toluene			X
087	Trichloroethylene		X	
088	Vinyl chloride (chloroethylene)	X		
089	Aldrin	X		
090	Dieldrin	X		
091	Chlordane (technical mixture and metabolites)	X		
092	4,4-DDT	X		
093	4,4-DDE (p,p-DDX)	X		
094	4,4-DDD (p,p-TDE)	X		
095	Alpha-endosulfan	X		
096	Beta-endosulfan	X		
097	Endosulfan sulfate	X		
098	Endrin	X		
099	Endrin aldehyde	X		
100	Heptachlor	X		
101	Heptachlor epoxide (BHC-hexachlorocyclo-hexane)	X		
102	Alpha-BHC	X		
103	Beta-BHC	X		
104	Gamma-BHC (lindane)	X		
105	Delta-BHC (PCB-poly-chlorinated biphenyls)	X		

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TABLE VI-1 Continued

106	PCB-1242 (Arochlor 1242)	X			
107	PCB-1254 (Arochlor 1254)	X			
108	PCB-1221 (Arochlor 1221)	X			
109	PCB-1232 (Arochlor 1232)	X			
110	PCB-1248 (Arochlor 1248)	X			
111	PCB-1260 (Arochlor 1260)	X			
112	PCB-1016 (Arochlor 1016)	X			
113	Toxaphene	X			
114	Antimony	X			
115	Arsenic	X			
116	Asbestos (NOT ANALYZED)				
117	Beryllium		X		
118	Cadmium				X
119	Chromium				X
120	Copper			X	
121	Cyanide, Total				X
122	Lead				X
123	Mercury				X
124	Nickel				X
125	Selenium	X			X
126	Silver		X [1]		
127	Thallium	X			
128	Zinc				X
129	2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) (NOT ANALYZED)				

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[1] For all subcategory elements except silver cathodes.

TABLE VI-2
PRIORITY POLLUTANT DISPOSITION
Calcium Subcategory

POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001 Acenaphthene					
002 Acrolein					
003 Acrylonitrile					
004 Benzene					
005 Benzidine					
006 Carbon tetrachloride (tetrachloromethane)					
007 Chlorobenzene					
008 1,2,4-trichlorobenzene					
009 Hexachlorobenzene					
010 1,2-dichloroethane					
011 1,1,1-trichlorethane					
012 Hexachloroethane					
013 1,1-dichloroethane					
014 1,1,2-trichloroethane					
015 1,1,2,2-tetrachloroethane					
016 Chloroethane					
017 Bis (chloromethyl) ether					
018 Bis (2-chloroethyl) ether					
019 2-chloroethyl vinyl ether (mixed)					
020 2-chloronaphthalene					
021 2,4,6-trichlorophenol					
022 Parachlorometa cresol					
023 Chloroform (trichloro-methane)					
024 2-chlorophenol					
025 1,2-dichlorobenzene					
026 1,3-dichlorobenzene					
027 1,4-dichlorobenzene					
028 3,3-dichlorobenzidine					
029 1,1-dichloroethylene					
030 1,2-trans-dichloroethylene					
031 2,4-dichlorophenol					
032 1,2-dichloropropane					
033 1,2-dichloropropylene (1,3-dichloropropene)					

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TABLE VI-2 Continued

034	2,4-dimethylphenol
035	2,4-dinitrotoluene
036	2,6-dinitrotoluene
037	1,2-diphenylhydrazine
038	Ethylbenzene
039	Fluoranthene
040	4-chlorophenyl phenyl ether
041	4-bromophenyl phenyl ether
042	Bis(2-chloroisopropyl) ether
043	Bis(2-chloroethoxy) methane
044	Methylene chloride (dichloromethane)
045	Methyl chloride (dichloromethane)
046	Methyl bromide (bromomethane)
047	Bromoform (tribromomethane)
048	Dichlorobromomethane
049	Trichlorofluoromethane
050	Dichlorodifluoromethane
051	Chlorodibromomethane
052	Hexachlorobutadiene
053	Hexachloromyclopentadiene
054	Isophorone
055	Naphthalene
056	Nitrobenzene
057	2-nitrophenol
058	4-nitrophenol
059	2,4-dinitrophenol
060	4,6-dinitro-o-cresol
061	N-nitrosodimethylamine
062	N-nitrosodiphenylamine
063	N-nitrosodi-n-propylamine
064	Pentachlorophenol
065	Phenol
066	Bis(2-ethylhexyl)phthalate
067	Butyl benzyl phthalate
068	Di-N-Butyl Phthalate
069	Di-n-octyl phthalate
070	Diethyl Phthalate
071	Dimethyl phthalate
072	1,2-benzanthracene

TABLE VI-2 Continued

(benzo(a)anthracene)

073 Benzo(a)pyrene (3,4-benzo-
      pyrene)
074 3,4-Benzofluoranthene
      (benzo(b)fluoranthene)
075 11,12-benzofluoranthene
      (benzo(b)fluoranthene)
076 Chrysene
077 Acenaphthylene
078 Anthracene
079 1,12-benzoperylene
      (benzo(ghi)perylene)
080 Fluorene
081 Phenanthrene
082 1,2,5,6-dibenzanthracene
      (dibenzo(,h)anthracene)
083 Indeno(1,2,3-cd) pyrene
      (2,3-o-pheynylene pyrene)
084 Pyrene
085 Tetrachloroethylene
086 Toluene
087 Trichloroethylene
088 Vinyl chloride (chloroethylene)
089 Aldrin
090 Dieldrin
091 Chlordane (technical mixture
      and metabolites)
092 4,4-DDT
093 4,4-DDE (p,p-DDX)
094 4,4-DDD (p,p-TDE)
095 Alpha-endosulfan
096 Beta-endosulfan
097 Endosulfan sulfate
098 Endrin
099 Endrin aldehyde
100 Heptachlor
101 Heptachlor epoxide
      (BHC-hexachlorocyclo-
      hexane)
102 Alpha-BHC
103 Beta-BHC
104 Gamma-BHC (lindane)
105 Delta-BHC (PCB-poly-
      chlorinated biphenyls)

TABLE VI-2 Continued

106   PCB-1242 (Arochlor 1242)
107   PCB-1254 (Arochlor 1254)
108   PCB-1221 (Arochlor 1221)
109   PCB-1232 (Arochlor 1232)
110   PCB-1248 (Arochlor 1248)
111   PCB-1260 (Arochlor 1260)
112   PCB-1016 (Arochlor 1016)
113   Toxaphene
114   Antimony
115   Arsenic
116   Asbestos
117   Beryllium
118   Cadmium
119   Chromium
120   Copper
121   Cyanide, Total
122   Lead
123   Mercury
124   Nickel
125   Selenium
126   Silver
127   Thallium

128   Zinc
129   2,3,7,8-tetrachloro-
     dibenzo-p-dioxin (TCDD) (NOT ANALYZED)

TABLE VI-3
PRIORITY POLLUTANT DISPOSITION

Lead Subcategory

	POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001	Acenaphthene		X			
002	Acrolein	X				
003	Acrylonitrile	X				
004	Benzene		X			
005	Benzidine	X				
006	Carbon tetrachloride (tetrachloromethane)	X				
007	Chlorobenzene	X				
008	1,2,4-trichlorobenzene	X				
009	Hexachlorobenzene	X				
010	1,2-dichloroethane	X				
011	1,1,1-trichlorethane				X	
012	Hexachloroethane	X				
013	1,1-dichloroethane	X				
014	1,1,2-trichloroethane	X				
015	1,1,2,2-tetrachloroethane	X				
016	Chloroethane	X				
017	Bis (chloromethyl) ether	X				
018	Bis (2-chloroethyl) ether	X				
019	2-chloroethyl vinyl ether (mixed)	X				
020	2-chloronaphthalene	X				
021	2,4,6-trichlorophenol		X			
022	Parachlorometa cresol	X				
023	Chloroform (trichloromethane)				X	
024	2-chlorophenol		X			
025	1,2-dichlorobenzene	X				
026	1,3-dichlorobenzene		X			
027	1,4-dichlorobenzene	X				
028	3,3-dichlorobenzidine	X				
029	1,1-dichloroethylene	X				
030	1,2-trans-dichloroethylene	X				
031	2,4-dichlorophenol		X			
032	1,2-dichloropropane	X				
033	1,2-dichloropropylene (1,3-dichloropropene)	X				

TABLE VI-3 Continued

No.	Compound				
034	2,4-dimethylphenol	X			
035	2,4-dinitrotoluene	X			
036	2,6-dinitrotoluene	X			
037	1,2-diphenylhydrazine	X			
038	Ethylbenzene		X		
039	Fluoranthene		X		
040	4-chlorophenyl phenyl ether	X			
041	4-bromophenyl phenyl ether	X			
042	Bis(2-chloroisopropyl) ether	X			
043	Bis(2-chloroethoxy) methane	X			
044	Methylene chloride (dichloromethane)		X		
045	Methyl chloride (dichloromethane)	X			
046	Methyl bromide (bromomethane)	X			
047	Bromoform (tribromomethane)	X			
048	Dichlorobromomethane		X		
049	Trichlorofluoromethane	X			
050	Dichlorodifluoromethane	X			
051	Chlorodibromomethane		X		
052	Hexachlorobutadiene	X			
053	Hexachloromyclopentadiene	X			
054	Isophorone	X			X
055	Naphthalene	X			
056	Nitrobenzene	X			
057	2-nitrophenol	X			
058	4-nitrophenol	X			
059	2,4-dinitrophenol	X			
060	4,6-dinitro-o-cresol	X			
061	N-nitrosodimethylamine	X			
062	N-nitrosodiphenylamine	X			
063	N-nitrosodi-n-propylamine	X			
064	Pentachlorophenol	X			
065	Phenol		X		
066	Bis(2-ethylhexyl)phthalate			X	
067	Butyl benzyl phthalate			X	
068	Di-N-Butyl Phthalate			X	
069	Di-n-octyl phthalate			X	
070	Diethyl Phthalate	X			
071	Dimethyl phthalate	X			
072	1,2-benzanthracene		X		

TABLE VI-3 Continued

	(benzo(a)anthracene)			
073	Benzo(a)pyrene (3,4-benzo-pyrene)		X	
074	3,4-Benzofluoranthene (benzo(b)fluoranthene)		X	
075	11,12-benzofluoranthene (benzo(b)fluoranthene)		X	
076	Chrysene		X	
077	Acenaphthylene	X		
078	Anthracene			X
079	1,12-benzoperylene (benzo(ghi)perylene)	X		
080	Fluorene		X	
081	Phenanthrene			X
082	1,2,5,6-dibenzanthracene (dibenzo(,h)anthracene)	X		
083	Indeno(1,2,3-cd) pyrene (2,3-o-pheynylene pyrene)	X		
084	Pyrene		X	
085	Tetrachloroethylene	X		
086	Toluene			X
087	Trichloroethylene		X	
088	Vinyl chloride (chloroethylene)	X		
089	Aldrin	X		
090	Dieldrin	X		
091	Chlordane (technical mixture and metabolites)	X		
092	4,4-DDT	X		
093	4,4-DDE (p,p-DDX)	X		
094	4,4-DDD (p,p-TDE)	X		
095	Alpha-endosulfan	X		
096	Beta-endosulfan	X		
097	Endosulfan sulfate	X		
098	Endrin	X		
099	Endrin aldehyde	X		
100	Heptachlor	X		
101	Heptachlor epoxide (BHC-hexachlorocyclo-hexane)		X	
102	Alpha-BHC	X		
103	Beta-BHC	X		
104	Gamma-BHC (lindane)	X		
105	Delta-BHC (PCB-poly-chlorinated biphenyls)	X		

TABLE VI-3 Continued

#	Compound	Col 1	Col 2	Col 3	Col 4
106	PCB-1242 (Arochlor 1242)	X			
107	PCB-1254 (Arochlor 1254)	X			
108	PCB-1221 (Arochlor 1221)	X			
109	PCB-1232 (Arochlor 1232)	X			
110	PCB-1248 (Arochlor 1248)	X			
111	PCB-1260 (Arochlor 1260)	X			
112	PCB-1016 (Arochlor 1016)	X			
113	Toxaphene	X			
114	Antimony				X
115	Arsenic			X	
116	Asbestos	X			
117	Beryllium		X		
118	Cadmium				X
119	Chromium				X
120	Copper				X
121	Cyanide, Total		X		
122	Lead				X
123	Mercury				X
124	Nickel				X
125	Selenium	X			
126	Silver				X
127	Thallium	X			
128	Zinc				X
129	2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) (NOT ANALYZED)				

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TABLE VI-4
PRIORITY POLLUTANT DISPOSITION

Leclanche Subcategory

	POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001	Acenaphthene	x				
002	Acrolein	x				
003	Acrylonitrile	x				
004	Benzene	x				
005	Benzidine	x				
006	Carbon tetrachloride (tetrachloromethane)	x				
007	Chlorobenzene	x				
008	1,2,4-trichlorobenzene	x				
009	Hexachlorobenzene	x				
010	1,2-dichloroethane	x				
011	1,1,1-trichlorethane	x				
012	Hexachloroethane	x				
013	1,1-dichloroethane	x				
014	1,1,2-trichloroethane	x				
015	1,1,2,2-tetrachloroethane		x			
016	Chloroethane	x				
017	Bis (chloromethyl) ether	x				
018	Bis (2-chloroethyl) ether	x				
019	2-chloroethyl vinyl ether (mixed)	x				
020	2-chloronaphthalene	x				
021	2,4,6-trichlorophenol	x				
022	Parachlorometa cresol	x				
023	Chloroform (trichloro-methane)			x		
024	2-chlorophenol	x				
025	1,2-dichlorobenzene	x				
026	1,3-dichlorobenzene	x				
027	1,4-dichlorobenzene	x				
028	3,3-dichlorobenzidine	x				
029	1,1-dichloroethylene	x				
030	1,2-trans-dichloroethylene	x				
031	2,4-dichlorophenol	x				
032	1,2-dichloropropane	x				
033	1,2-dichloropropylene (1,3-dichloropropene)	x				

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TABLE VI-4 Continued

No.	Compound			
034	2,4-dimethylphenol	X		
035	2,4-dinitrotoluene	X		
036	2,6-dinitrotoluene	X		
037	1,2-diphenylhydrazine	X		
038	Ethylbenzene	X		
039	Fluoranthene	X		
040	4-chlorophenyl phenyl ether	X		
041	4-bromophenyl phenyl ether	X		
042	Bis(2-chloroisopropyl) ether	X		
043	Bis(2-chloroethoxy) methane	X		
044	Methylene chloride (dichloromethane)		X	
045	Methyl chloride (dichloromethane)	X		
046	Methyl bromide (bromomethane)	X		
047	Bromoform (tribromo-methane)	X		
048	Dichlorobromomethane		X	
049	Trichlorofluoromethane	X		
050	Dichlorodifluoromethane	X		
051	Chlorodibromomethane		X	
052	Hexachlorobutadiene	X		
053	Hexachloromyclopenta-diene	X		
054	Isophorone	X		
055	Naphthalene	X		
056	Nitrobenzene	X		
057	2-nitrophenol	X		
058	4-nitrophenol	X		
059	2,4-dinitrophenol	X		
060	4,6-dinitro-o-cresol	X		
061	N-nitrosodimethylamine	X		
062	N-nitrosodiphenylamine	X		
063	N-nitrosodi-n-propylamine	X		
064	Pentachlorophenol	X		
065	Phenol		X	
066	Bis(2-ethylhexyl)phthalate		X	
067	Butyl benzyl phthalate		X	
068	Di-N-Butyl Phthalate		X	
069	Di-n-octyl phthalate	X		X
070	Diethyl Phthalate			
071	Dimethyl phthalate		X	
072	1,2-benzanthracene			

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TABLE VI-4 Continued

	(benzo(a)anthracene)	x
073	Benzo(a)pyrene (3,4-benzo-pyrene)	x
074	3,4-Benzofluoranthene (benzo(b)fluoranthene)	x
075	11,12-benzofluoranthene (benzo(b)fluoranthene)	x
076	Chrysene '	x
077	Acenaphthylene	x
078	Anthracene	x
079	1,12-benzoperylene (benzo(ghi)perylene)	x
080	Fluorene	x
081	Phenanthrene	x
082	1,2,5,6-dibenzanthracene (dibenzo(,h)anthracene)	x
083	Indeno(1,2,3-cd) pyrene (2,3-o-pheynylene pyrene)	x
084	Pyrene	x
085	Tetrachloroethylene	x
086	Toluene	(x)
087	Trichloroethylene	x
088	Vinyl chloride (chloroethylene)	x
089	Aldrin	x
090	Dieldrin	x
091	Chlordane (technical mixture and metabolites)	x
092	4,4-DDT	x
093	4,4-DDE (p,p-DDX)	x
094	4,4-DDD (p,p-TDE)	x
095	Alpha-endosulfan	x
096	Beta-endosulfan	x
097	Endosulfan sulfate	x
098	Endrin	x
099	Endrin aldehyde	x
100	Heptachlor	x
101	Heptachlor epoxide (BHC-hexachlorocyclo-hexane)	x
102	Alpha-BHC	x
103	Beta-BHC	x
104	Gamma-BHC (lindane)	x
105	Delta-BHC (PCB-poly-chlorinated biphenyls)	x

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TABLE VI-4 Continued

#	Compound				
106	PCB-1242 (Arochlor 1242)	x			
107	PCB-1254 (Arochlor 1254)	x			
108	PCB-1221 (Arochlor 1221)	x			
109	PCB-1232 (Arochlor 1232)	x			
110	PCB-1248 (Arochlor 1248)	x			
111	PCB-1260 (Arochlor 1260)	x			
112	PCB-1016 (Arochlor 1016)	x			
113	Toxaphene	x		x	
114	Antimony				
115	Arsenic				x
116	Asbestos	x			
117	Beryllium		x		
118	Cadmium				x
119	Chromium				x
120	Copper				
121	Cyanide, Total			x	
122	Lead				x
123	Mercury				x
124	Nickel				x
125	Selenium				x
126	Silver		x		
127	Thallium	x			
128	Zinc				x
129	2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) (NOT ANALYZED)				

TABLE VI-5
PRIORITY POLLUTANT DISPOSITION
Lithium Subcategory

POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001 Acenaphthene					
002 Acrolein					
003 Acrylonitrile					
004 Benzene					
005 Benzidine					
006 Carbon tetrachloride (tetrachloromethane)					
007 Chlorobenzene					
008 1,2,4-trichlorobenzene					
009 Hexachlorobenzene					
010 1,2-dichloroethane					
011 1,1,1-trichlorethane					
012 Hexachloroethane					
013 1,1-dichloroethane					
014 1,1,2-trichloroethane					
015 1,1,2,2-tetrachloroethane					
016 Chloroethane					
017 Bis (chloromethyl) ether					
018 Bis (2-chloroethyl) ether					
019 2-chloroethyl vinyl ether (mixed)					
020 2-chloronaphthalene					
021 2,4,6-trichlorophenol					
022 Parachlorometa cresol					
023 Chloroform (trichloro-methane)					
024 2-chlorophenol					
025 1,2-dichlorobenzene					
026 1,3-dichlorobenzene					
027 1,4-dichlorobenzene					
028 3,3-dichlorobenzidine					
029 1,1-dichloroethylene					
030 1,2-trans-dichloroethylene					
031 2,4-dichlorophenol					
032 1,2-dichloropropane					
033 1,2-dichloropropylene (1,3-dichloropropene)					

TABLE VI-5 Continued

034	2,4-dimethylphenol
035	2,4-dinitrotoluene
036	2,6-dinitrotoluene
037	1,2-diphenylhydrazine
038	Ethylbenzene
039	Fluoranthene
040	4-chlorophenyl phenyl ether
041	4-bromophenyl phenyl ether
042	Bis(2-chloroisopropyl) ether
043	Bis(2-chloroethoxy) methane
044	Methylene chloride (dichloromethane)
045	Methyl chloride (dichloromethane)
046	Methyl bromide (bromomethane)
047	Bromoform (tribromo-methane)
048	Dichlorobromomethane
049	Trichlorofluoromethane
050	Dichlorodifluoromethane
051	Chlorodibromomethane
052	Hexachlorobutadiene
053	Hexachloromyclopenta-diene
054	Isophorone
055	Naphthalene
056	Nitrobenzene
057	2-nitrophenol
058	4-nitrophenol
059	2,4-dinitrophenol
060	4,6-dinitro-o-cresol
061	N-nitrosodimethylamine
062	N-nitrosodiphenylamine
063	N-nitrosodi-n-propylamine
064	Pentachlorophenol
065	Phenol
066	Bis(2-ethylhexyl)phthalate
067	Butyl benzyl phthalate
068	Di-N-Butyl Phthalate
069	Di-n-octyl phthalate
070	Diethyl Phthalate
071	Dimethyl phthalate
072	1,2-benzanthracene

TABLE VI-5 Continued

(benzo(a)anthracene)

073 Benzo(a)pyrene (3,4-benzo-
  pyrene)

074 3,4-Benzofluoranthene
  (benzo(b)fluoranthene)

075 11,12-benzofluoranthene
  (benzo(b)fluoranthene)

076 Chrysene

077 Acenaphthylene

078 Anthracene

079 1,12-benzoperylene
  (benzo(ghi)perylene)

080 Fluorene

081 Phenanthrene

082 1,2,5,6-dibenzanthracene
  (dibenzo(,h)anthracene)

083 Indeno(1,2,3-cd) pyrene
  (2,3-o-pheynylene pyrene)

084 Pyrene

085 Tetrachloroethylene

086 Toluene

087 Trichloroethylene

088 Vinyl chloride (chloroethylene)

089 Aldrin

090 Dieldrin

091 Chlordane (technical mixture
  and metabolites)

092 4,4-DDT

093 4,4-DDE (p,p-DDX)

094 4,4-DDD (p,p-TDE)

095 Alpha-endosulfan

096 Beta-endosulfan

097 Endosulfan sulfate

098 Endrin

099 Endrin aldehyde

100 Heptachlor

101 Heptachlor epoxide
  (BHC-hexachlorocyclo-
   hexane)

102 Alpha-BHC
103 Beta-BHC
104 Gamma-BHC (lindane)
105 Delta-BHC (PCB-poly-
  chlorinated biphenyls)

TABLE VI-5 Continued

106	PCB-1242 (Arochlor 1242)
107	PCB-1254 (Arochlor 1254)
108	PCB-1221 (Arochlor 1221)
109	PCB-1232 (Arochlor 1232)
110	PCB-1248 (Arochlor 1248)
111	PCB-1260 (Arochlor 1260)
112	PCB-1016 (Arochlor 1016)
113	Toxaphene
114	Antimony
115	Arsenic
116	Asbestos
117	Beryllium
118	Cadmium
119	Chromium
120	Copper
121	Cyanide, Total
122	Lead
123	Mercury
124	Nickel
125	Selenium
126	Silver
127	Thallium
128	Zinc
129	2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) (NOT ANALYZED)

TABLE VI-6
PRIORITY POLLUTANT DISPOSITION
Magnesium Subcategory

POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001 Acenaphthene					
002 Acrolein					
003 Acrylonitrile					
004 Benzene					
005 Benzidine					
006 Carbon tetrachloride (tetrachloromethane)					
007 Chlorobenzene					
008 1,2,4-trichlorobenzene					
009 Hexachlorobenzene					
010 1,2-dichloroethane					
011 1,1,1-trichlorethane					
012 Hexachloroethane					
013 1,1-dichloroethane					
014 1,1,2-trichloroethane					
015 1,1,2,2-tetrachloroethane					
016 Chloroethane					
017 Bis (chloromethyl) ether					
018 Bis (2-chloroethyl) ether					
019 2-chloroethyl vinyl ether (mixed)					
020 2-chloronaphthalene					
021 2,4,6-trichlorophenol					
022 Parachlorometa cresol					
023 Chloroform (trichloro-methane)					
024 2-chlorophenol					
025 1,2-dichlorobenzene					
026 1,3-dichlorobenzene					
027 1,4-dichlorobenzene					
028 3,3-dichlorobenzidine					
029 1,1-dichloroethylene					
030 1,2-trans-dichloroethylene					
031 2,4-dichlorophenol					
032 1,2-dichloropropane					
033 1,2-dichloropropylene (1,3-dichloropropene)					

TABLE VI-6 Continued

034	2,4-dimethylphenol
035	2,4-dinitrotoluene
036	2,6-dinitrotoluene
037	1,2-diphenylhydrazine
038	Ethylbenzene
039	Fluoranthene
040	4-chlorophenyl phenyl ether
041	4-bromophenyl phenyl ether
042	Bis(2-chloroisopropyl) ether
043	Bis(2-chloroethoxy) methane
044	Methylene chloride (dichloromethane)
045	Methyl chloride (dichloromethane)
046	Methyl bromide (bromomethane)
047	Bromoform (tribromo-methane)
048	Dichlorobromomethane
049	Trichlorofluoromethane
050	Dichlorodifluoromethane
051	Chlorodibromomethane
052	Hexachlorobutadiene
053	Hexachloromyclopenta-diene
054	Isophorone
055	Naphthalene
056	Nitrobenzene
057	2-nitrophenol
058	4-nitrophenol
059	2,4-dinitrophenol
060	4,6-dinitro-o-cresol
061	N-nitrosodimethylamine
062	N-nitrosodiphenylamine
063	N-nitrosodi-n-propylamine
064	Pentachlorophenol
065	Phenol
066	Bis(2-ethylhexyl)phthalate
067	Butyl benzyl phthalate
068	Di-N-Butyl Phthalate
069	Di-n-octyl phthalate
070	Diethyl Phthalate
071	Dimethyl phthalate
072	1,2-benzanthracene

TABLE VI-6 Continued

	(benzo(a)anthracene)
073	Benzo(a)pyrene (3,4-benzo-pyrene)
074	3,4-Benzofluoranthene (benzo(b)fluoranthene)
075	11,12-benzofluoranthene (benzo(b)fluoranthene)
076	Chrysene
077	Acenaphthylene
078	Anthracene
079	1,12-benzoperylene (benzo(ghi)perylene)
080	Fluorene
081	Phenanthrene
082	1,2,5,6-dibenzanthracene (dibenzo(,h)anthracene)
083	Indeno(1,2,3-cd) pyrene (2,3-o-pheynylene pyrene)
084	Pyrene
085	Tetrachloroethylene
086	Toluene
087	Trichloroethylene
088	Vinyl chloride (chloroethylene)
089	Aldrin
090	Dieldrin
091	Chlordane (technical mixture and metabolites)
092	4,4-DDT
093	4,4-DDE (p,p-DDX)
094	4,4-DDD (p,p-TDE)
095	Alpha-endosulfan
096	Beta-endosulfan
097	Endosulfan sulfate
098	Endrin
099	Endrin aldehyde
100	Heptachlor
101	Heptachlor epoxide (BHC-hexachlorocyclo-hexane)
102	Alpha-BHC
103	Beta-BHC
104	Gamma-BHC (lindane)
105	Delta-BHC (PCB-poly-chlorinated biphenyls)

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TABLE VI-6 Continued

106	PCB-1242 (Arochlor 1242)
107	PCB-1254 (Arochlor 1254)
108	PCB-1221 (Arochlor 1221)
109	PCB-1232 (Arochlor 1232)
110	PCB-1248 (Arochlor 1248)
111	PCB-1260 (Arochlor 1260)
112	PCB-1016 (Arochlor 1016)
113	Toxaphene
114	Antimony
115	Arsenic
116	Asbestos
117	Beryllium
118	Cadmium
119	Chromium
120	Copper
121	Cyanide, Total
122	Lead
123	Mercury
124	Nickel
125	Selenium
126	Silver
127	Thallium
128	Zinc
129	2,3,7,8-tetrachloro- dibenzo-p-dioxin (TCDD) (NOT ANALYZED)

TABLE VI-7
PRIORITY POLLUTANT DISPOSITION

Zinc Subcategory

	POLLUTANT	NOT DETECTED	NOT QUANTIFICABLE	ENVIRONMENTALLY INSIGNIFICANT	NOT TREATABLE	REGULATION CONSIDERED
001	Acenaphthene	X				
002	Acrolein	X				
003	Acrylonitrile	X				
004	Benzene		X			
005	Benzidine	X				
006	Carbon tetrachloride (tetrachloromethane)	X				
007	Chlorobenzene	X				
008	1,2,4-trichlorobenzene	X				
009	Hexachlorobenzene	X				
010	1,2-dichloroethane	X				
011	1,1,1-trichlorethane			X		
012	Hexachloroethane	X				
013	1,1-dichloroethane			X		
014	1,1,2-trichloroethane		X			
015	1,1,2,2-tetrachloroethane	X				
016	Chloroethane	X				
017	Bis (chloromethyl) ether	X				
018	Bis (2-chloroethyl) ether	X				
019	2-chloroethyl vinyl ether (mixed)	X				
020	2-chloronaphthalene	X				
021	2,4,6-trichlorophenol		X			
022	Parachlorometa cresol	X				
023	Chloroform (trichloromethane)			X		
024	2-chlorophenol		X			
025	1,2-dichlorobenzene	X				
026	1,3-dichlorobenzene	X				
027	1,4-dichlorobenzene	X				
028	3,3-dichlorobenzidine	X				
029	1,1-dichloroethylene		X			
030	1,2-trans-dichloroethylene		X			
031	2,4-dichlorophenol	X				
032	1,2-dichloropropane	X				
033	1,2-dichloropropylene (1,3-dichloropropene)	X				

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TABLE VI-7 Continued

		Col 1	Col 2	Col 3
034	2,4-dimethylphenol	X		
035	2,4-dinitrotoluene	X		
036	2,6-dinitrotoluene	X		
037	1,2-diphenylhydrazine	X		
038	Ethylbenzene			X
039	Fluoranthene	X		
040	4-chlorophenyl phenyl ether	X		
041	4-bromophenyl phenyl ether	X		
042	Bis(2-chloroisopropyl) ether	X		
043	Bis(2-chloroethoxy) methane	X		
044	Methylene chloride (dichloromethane)			X
045	Methyl chloride (dichloromethane)	X		
046	Methyl bromide (bromomethane)	X		
047	Bromoform (tribromo-methane)	X		
048	Dichlorobromomethane	X		
049	Trichlorofluoromethane	X		
050	Dichlorodifluoromethane	X		
051	Chlorodibromomethane	X		
052	Hexachlorobutadiene	X		
053	Hexachloromyclopenta-diene	X		
054	Isophorone	X		
055	Naphthalene			X
056	Nitrobenzene	X		
057	2-nitrophenol	X		
058	4-nitrophenol	X		
059	2,4-dinitrophenol	X		
060	4,6-dinitro-o-cresol	X		
061	N-nitrosodimethylamine	X		
062	N-nitrosodiphenylamine	X		
063	N-nitrosodi-n-propylamine ·	X		
064	Pentachlorophenol			X
065	Phenol			X
066	Bis(2-ethylhexyl)phthalate			X
067	Butyl benzyl phthalate		X	
068	Di-N-Butyl Phthalate		X	
069	Di-n-octyl phthalate	X		
070	Diethyl Phthalate		X	
071	Dimethyl phthalate	X		
072	1,2-benzanthracene			

TABLE VI-7 Continued

		Col 1	Col 2
	(benzo(a)anthracene)	x	
073	Benzo(a)pyrene (3,4-benzo-pyrene)	x	
074	3,4-Benzofluoranthene (benzo(b)fluoranthene)	x	
075	11,12-benzofluoranthene (benzo(b)fluoranthene)	x	
076	Chrysene	x	
077	Acenaphthylene	x	
078	Anthracene		x
079	1,12-benzoperylene (benzo(ghi)perylene)	x	
080	Fluorene	x	
081	Phenanthrene		x
082	1,2,5,6-dibenzanthracene (dibenzo(,h)anthracene)	x	
083	Indeno(1,2,3-cd) pyrene (2,3-o-pheynylene pyrene)	x	
084	Pyrene	x	
085	Tetrachloroethylene		x
086	Toluene		x
087	Trichloroethylene		x
088	Vinyl chloride (chloroethylene)	x	
089	Aldrin	x	
090	Dieldrin	x	
091	Chlordane (technical mixture and metabolites)	x	
092	4,4-DDT	x	
093	4,4-DDE (p,p-DDX)	x	
094	4,4-DDD (p,p-TDE)	x	
095	Alpha-endosulfan	x	
096	Beta-endosulfan	x	
097	Endosulfan sulfate	x	
098	Endrin	x	
099	Endrin aldehyde	x	
100	Heptachlor	x	
101	Heptachlor epoxide (BHC-hexachlorocyclo-hexane)	x	
102	Alpha-BHC	x	
103	Beta-BHC	x	
104	Gamma-BHC (lindane)	x	
105	Delta-BHC (PCB-poly-chlorinated biphenyls)	x	

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TABLE VI-7 Continued

106	PCB-1242 (Arochlor 1242)	x		
107	PCB-1254 (Arochlor 1254)	x		
108	PCB-1221 (Arochlor 1221)	x		
109	PCB-1232 (Arochlor 1232)	x		
110	PCB-1248 (Arochlor 1248)	x		
111	PCB-1260' (Arochlor 1260)	x		
112	PCB-1016 (Arochlor 1016)	x		
113	Toxaphene	x		
114	Antimony	x		
115	Arsenic			x
116	Asbestos	x		
117	Beryllium		x	
118	Cadmium			x
119	Chromium			x
120	Copper			x
121	Cyanide, Total			x
122	Lead			x
123	Mercury			x
124	Nickel			x
125	Selenium			x
126	Silver			x
127	Thallium	x		
128	Zinc			x
129	2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) (NOT ANALYZED)			

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TABLE VI-8

Other Pollutants Considered for Regulation

	Cadmium	Lead	Leclanche	Zinc
			Subcategory	
Aluminum				x
Cobalt	x			
Iron		x		x
Manganese			x	x
Oil & Grease	x	x	x	x
TSS	x	x	x	x
pH	x	x	x	x

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SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section describes the treatment techniques currently used or available to remove or recover wastewater pollutants normally generated by the battery manufacturing industrial point source category. Included are discussions of individual end-of-pipe treatment technologies and in-plant technologies.

END-OF-PIPE TREATMENT TECHNOLOGIES

Individual recovery and treatment technologies are described which are used or are suitable for use in treating wastewater discharges from battery manufacturing facilities. Each description includes a functional description and discussions of application and performance, advantages and limitations, operational factors (reliability, maintainability, solid waste aspects), and demonstration status. The treatment processes described include both technologies presently demonstrated within the battery manufacturing category, and technologies demonstrated in treatment of similar wastes in other industries.

Battery manufacturing wastewater streams characteristically contain significant levels of toxic inorganics. Cadmium, chromium, lead, mercury, nickel, silver and zinc are found in battery manufacturing wastewater streams at substantial concentrations. These toxic inorganic pollutants constitute the most significant wastewater pollutants in this category.

In general, these pollutants are removed by chemical precipitation and sedimentation or filtration. Most of them may be effectively removed by precipitation of metal hydroxides or carbonates utilizing the reaction with lime, sodium hydroxide, or sodium carbonate. For some, improved removals are provided by the use of sodium sulfide or ferrous sulfide to precipitate the pollutants as sulfide compounds with very low solubilities.

Discussion of end-of-pipe treatment technologies is divided into three parts: the major technologies; the effectiveness of major technologies; and minor end-of-pipe technologies.

MAJOR TECHNOLOGIES

In Sections IX and X, the rationale for selecting treatment systems is discussed. The individual technologies used in the system are described here. The major end-of-pipe technologies are: chemical

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precipitation of dissolved metals, chemical reduction of hexavalent chromium, cyanide precipitation, granular bed filtration, pressure filtration, settling of suspended solids, and skimming of oil. In practice, precipitation of metals and settling of the resulting precipitates is often a unified two-step operation. Suspended solids originally present in raw wastewaters are not appreciably affected by the precipitation operation and are removed with the precipitated metals in the settling operations. Settling operations can be evaluated independently of hydroxide or other chemical precipitation operations, but hydroxide and other chemical precipitation operations can only be evaluated in combination with a solids removal operation.

Chemical Precipitation

Dissolved toxic metal ions and certain anions may be chemically precipitated for removal by physical means such as sedimentation, filtration, or centrifugation. Several reagents are commonly used to effect this precipitation.

1) Alkaline compounds such as lime or sodium hydroxide may be used to precipitate many toxic metal ions as metal hydroxides. Lime also may precipitate phosphates as insoluble calcium phosphate and fluorides as calcium fluoride.

2) Both "soluble" sulfides such as hydrogen sulfide or sodium sulfide and "insoluble" sulfides such as ferrous sulfide may be used to precipitate many heavy metal ions as insoluble metal sulfides.

3) Ferrous sulfate, zinc sulfate or both (as is required) may be used to precipitate cyanide as a ferro or zinc ferricyanide complex.

4) Carbonate precipitates may be used to remove metals either by direct precipitation using a carbonate reagent such as calcium carbonate or by converting hydroxides into carbonates using carbon dioxide.

These treatment chemicals may be added to a flash mixer or rapid mix tank, to a presettling tank, or directly to a clarifier or other settling device. Because metal hydroxides tend to be colloidal in nature, coagulating agents may also be added to facilitate settling. After the solids have been removed, final pH adjustment may be required to reduce the high pH created by the alkaline treatment chemicals.

Chemical precipitation as a mechanism for removing metals from wastewater is a complex process of at least two steps - precipitation of the unwanted metals and removal of the precipitate. Some small amount of metal will remain dissolved in the wastewater after complete precipitation. The amount of residual dissolved metal depends on the

treatment chemicals used and related factors. The effectiveness of this method of removing any specific metal depends on the fraction of the specific metal in the raw waste (and hence in the precipitate) and the effectiveness of suspended solids removal.

Application and Performance. Chemical precipitation is used in battery manufacturing for precipitation of dissolved metals. It can be used to remove metal ions such as aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, tin and zinc. The process is also applicable to any substance that can be transformed into an insoluble form such as fluorides, phosphates, soaps, sulfides and others. Because it is simple and effective, chemical precipitation is extensively used for industrial waste treatment.

The performance of chemical precipitation depends on several variables. The most important factors affecting precipitation effectiveness are:

1. Maintenance of an alkaline pH throughout the precipitation reaction and subsequent settling;

2. Addition of a sufficient excess of treatment ions to drive the precipitation reaction to completion;

3. Addition of an adequate supply of sacrifical ions (such as iron or aluminum) to ensure precipitation and removal of specific target ions; and

4. Effective removal of precipitated solids.

Control of pH. Irrespective of the solids removal technology employed, proper control of pH is absolutely essential for favorable performance of precipitation-sedimentation technologies. This is clearly illustrated by solubility curves for selected metals hydroxides and sulfides shown in Figure VII-1, (Page 571) and by plotting effluent zinc concentrations against pH as shown in Figure VII-2 (Page 572). It is partially illustrated by data obtained from 3 consecutive days of sampling at one metal processing plant as displayed in Table VII-1.

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TABLE VII-1
pH CONTROL EFFECT ON METALS REMOVAL

	Day 1 In	Day 1 Out	Day 2 In	Day 2 Out	Day 3 In	Day 3 Out
pH Range (mg/l)	2.4-3.4	8.5-8.7	1.0-3.0	5.0-6.0	2.0-5.0	6.5-8.1
TSS	39	8	16	19	16	7
Copper	312	0.22	120	5.12	107	0.66
Zinc	250	0.31	32.5	25.0	43.8	0.66

This treatment system uses lime precipitation (pH adjustment) followed by coagulant addition and sedimentation. Samples were taken before (in) and after (out) the treatment system. The best treatment for removal of copper and zinc was achieved on day one, when the pH was maintained at a satisfactory level. The poorest treatment was found on the second day, when the pH slipped to an unacceptably low level and intermediate values were were achieved on the third day when pH values were less than desirable but in between the first and second days.

Sodium hydroxide is used by one facility for pH adjustment and chemical precipitation, followed by settling (sedimentation and a polishing lagoon) of precipitated solids. Samples were taken prior to caustic addition and following the polishing lagoon. Flow through the system is approximately 6,000 gal/hr.

TABLE VII-2
Effectiveness of Sodium Hydroxide for Metals Removal

	Day 1 In	Day 1 Out	Day 2 In	Day 2 Out	Day 3 In	Day 3 Out
pH Range (mg/l)	2.1-2.9	9.0-9.3	2.0-2.4	8.7-9.1	2.0-2.4	8.6-9.1
Cr	0.097	0.0	0.057	0.005	0.068	0.005
Cu	0.063	0.018	0.078	0.014	0.053	0.019
Fe	9.24	0.76	15.5	0.92	9.41	0.95

Pb	1.0	0.11	1.36	0.13	1.45	0.11
Mn	0.11	0.06	0.12	0.044	0.11	0.044
Ni	0.077	0.011	0.036	0.009	0.069	0.011
Zn	.054	0.0	0.12	0.0	0.19	0.037
TSS		13		11		11

These data indicate that the system was operated efficiently. Effluent pH was controlled within the range of 8.6-9.3, and, while raw waste loadings were not unusually high, most toxic metals were removed to very low concentrations.

Lime and sodium hydroxide are sometimes used to precipitate metals. Data developed from plant 40063, a facility with a metal bearing wastewater, exemplify efficient operation of a chemical precipitation and settling system. Table VII-3 shows sampling data from this system, which uses lime and sodium hydroxide for pH adjustment, chemical precipitation, polyelectrolyte flocculant addition, and sedimentation. Samples were taken of the raw waste influent to the system and of the clarifier effluent. Flow through the system is approximately 5,000 gal/hr.

TABLE VII-3
Effectiveness of Lime and Sodium Hydroxide for Metals Removal

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range (mg/l)	9.2-9.6	8.3-9.8	9.2	7.6-8.1	9.6	7.8-8.2
Al	37.3	0.35	38.1	0.35	29.9	0.35
Cu	0.65	0.003	0.63	0.003	0.72	0.003
Fe	137	0.49	110	0.57	208	0.58
Mn	175	0.12	205	0.012	245	0.12
Ni	6.86	0.0	5.84	0.0	5.63	0.0
Se	28.6	0.0	30.2	0.0	27.4	0.0
Ti	143	0.0	125	0.0	115	0.0
Zn	18.5	0.027	16.2	0.044	17.0	0.01
TSS	4390	9	3595	13	2805	13

At this plant, effluent TSS levels were below 15 mg/l on each day, despite average raw waste TSS concentrations of over 3500 mg/l. Effluent pH was maintained at approximately 8, lime addition was sufficient to precipitate the dissolved metal ions, and the flocculant addition and clarifier retention served to remove effectively the precipitated solids.

Sulfide precipitation is sometimes used to precipitate metals resulting in improved metals removals. Most metal sulfides are less soluble than hydroxides and the precipitates are frequently more dependably removed from water. Solubilities for selected metal hydroxide, carbonate and sulfide precipitates are shown in Table VII-4. Sulfide precipitation is particularly effective in removing specific metals such as silver and mercury. Sampling data from three industrial plants using sulfide precipitation appear in Table VII-5.

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TABLE VII-4

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF SELECTED METALS IN PURE WATER

Metal	Solubility of metal ion, mg/l		
	As Hydroxide	As Carbonate	As sulfide
Cadmium (Cd^{++})	2.3×10^{-5}	1.0×10^{-4}	6.7×10^{-10}
Chromium (Cr^{+++})	8.4×10^{-4}		No precipitate
Cobalt (Co^{++})	2.2×10^{-1}		1.0×10^{-8}
Copper (Cu^{++})	2.2×10^{-2}		5.8×10^{-18}
Iron (Fe^{++})	8.9×10^{-1}		3.4×10^{-5}
Lead (Pb^{++})	2.1	7.0×10^{-3}	3.8×10^{-9}
Manganese (Mn^{++})	1.2		2.1×10^{-3}
Mercury (Hg^{++})	3.9×10^{-4}	3.9×10^{-2}	9.0×10^{-20}
Nickel (Ni^{++})	6.9×10^{-3}	1.9×10^{-1}	6.9×10^{-8}
Silver (Ag^{+})	13.3	2.1×10^{-1}	7.4×10^{-12}
Tin (Sn^{++})	1.1×10^{-4}		3.8×10^{-8}
Zinc (Zn^{++})	1.1	7.0×10^{-4}	2.3×10^{-7}

TABLE VII-5

SAMPLING DATA FROM SULFIDE PRECIPITATION-SEDIMENTATION SYSTEMS

Treatment	Lime, FeS, Poly-electrolyte, Settle, Filter		Lime, FeS, Poly-electrolyte, Settle, Filter		NaOH, Ferric Chloride, Na_2S Clarify (1 stage)	
	In	Out	In	Out	In	Out
pH (mg/l)	5.0-6.8	8-9	7.7	7.38		
Cr+6	25.6	<0.014	0.022	<0.020	11.45	<.005
Cr	32.3	<0.04	2.4	<0.1	18.35	<.005
Cu	–	–	–	–	0.029	0.003
Fe	0.52	0.10	108	0.6	–	–
Ni	–	–	0.68	<0.1	–	–
Zn	39.5	<0.07	33.9	<0.1	0.060	0.009

In all cases except iron, effluent concentrations are below 0.1 mg/l and in many cases below 0.01 mg/l for the three plants studied.

Sampling data from several chlorine-caustic manufacturing plants using sulfide precipitation demonstrate effluent mercury concentrations varying between 0.009 and 0.03 mg/l. As shown in Figure VII-1, the solubilities of PbS and Ag_2S are lower at alkaline pH levels than either the corresponding hydroxides or other sulfide compounds. This implies that removal performance for lead and silver sulfides should be comparable to or better than that shown for the metals listed in Table VII-13. Bench scale tests on several types of metal finishing and manufacturing wastewater indicate that metals removal to levels of less than 0.05 mg/l and in some cases less than 0.01 mg/l are common in systems using sulfide precipitation followed by clarification. Some of the bench scale data, particularly in the case of lead, do not support such low effluent concentrations. However, lead is consistently removed to very low levels (less than 0.02 mg/l) in systems using hydroxide and carbonate precipitation and sedimentation.

Of particular interest is the ability of sulfide to precipitate hexavalent chromium (Cr+6) without prior reduction to the tri-valent state as is required in the hydroxide process. When ferrous sulfide is used as the precipitant, iron and sulfide act as reducing agents for the hexavalent chromium according to the reaction:

$$CrO_3 + FeS + 3H_2O = Fe(OH)_3 + Cr(OH)_3 + S$$
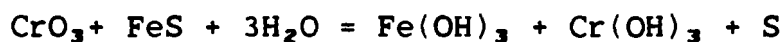
The sludge produced in this reaction consists mainly of ferric hydroxides, chromic hydroxides and various metallic sulfides. Some excess hydroxyl ions are generated in this process, possibly requiring a downward re-adjustment of pH.

Based on the available data, Table VII-6 shows the minimum reliably attainable effluent concentrations for sulfide precipitation-sedimentation systems. These values are used to calculate performance predictions of sulfide precipitation-sedimentation systems.

TABLE VII-6

SULFIDE PRECIPITATION-SEDIMENTATION PERFORMANCE

Parameter	Treated Effluent (mg/l)
Cd	0.01
CrT	0.05
Cu	0.05
Pb	0.01
Hg	0.03
Ni	0.05
Ag	0.05
Zn	0.01

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Carbonate precipitation is sometimes used to precipitate metals, especially where precipitated metals values are to be recovered. The solubility of most metal carbonates is intermediate between hydroxide and sulfide solubilities; in addition, carbonates form easily filtered precipitates.

Carbonate ions appear to be particularly useful in precipitating lead and antimony. Sodium carbonate has been observed being added at treatment to improve lead precipitation and removal in some industrial plants. The lead hydroxide and lead carbonate solubility curves displayed in Figure VII-12 (Page 582) explain this phenomenon.

Advantages and Limitations. Chemical precipitation has proven to be an effective technique for removing many pollutants from industrial wastewater. It operates at ambient conditions and is well suited to automatic control. The use of chemical precipitation may be limited because of interference by chelating agents, because of possible chemical interference mixed wastewaters and treatment chemicals, or because of the potentially hazardous situation involved with the storage and handling of those chemicals. Lime is usually added as a slurry when used in hydroxide precipitation. The slurry must be kept well mixed and the addition lines periodically checked to prevent blocking of the lines, which may result from a buildup of solids. Also, hydroxide precipitation usually makes recovery of the precipitated metals difficult, because of the heterogeneous nature of most hydroxide sludges.

The major advantage of the sulfide precipitation process is that the extremely low solubility of most metal sulfides, promotes very high metal removal efficiencies; the sulfide process also has the ability to remove chromates and dichromates without preliminary reduction of the chromium to its trivalent state. In addition, sulfide can precipitate metals complexed with most complexing agents. The process demands care, however, in maintaining the pH of the solution at approximately 10 in order to prevent the generation of toxic hydrogen sulfide gas. For this reason, ventilation of the treatment tanks may be a necessary precaution in most installations. The use of ferrous sulfide reduces or virtually eliminates the problem of hydrogen sulfide evolution. As with hydroxide precipitation, excess sulfide ion must be present to drive the precipitation reaction to completion. Since the sulfide ion itself is toxic, sulfide addition must be carefully controlled to maximize heavy metals precipitation with a minimum of excess sulfide to avoid the necessity of post treatment. At very high excess sulfide levels and high pH, soluble mercury-sulfide compounds may also be formed. Where excess sulfide is present, aeration of the effluent stream can aid in oxidizing residual sulfide to the less harmful sodium sulfate (Na_2SO_4). The cost of sulfide precipitants is high in comparison with hydroxide precipitants, and disposal of metallic sulfide sludges may pose

problems. An essential element in effective sulfide precipitation is the removal of precipitated solids from the wastewater and proper disposal in an appropriate site. Sulfide precipitation will also generate a higher volume of sludge, than hydroxide precipitation, resulting in higher disposal and dewatering costs. This is especially true when ferrous sulfide is used as the precipitant.

Sulfide precipitation may be used as a polishing treatment after hydroxide precipitation-sedimentation. This treatment configuration may provide the better treatment effectiveness of sulfide precipitation while minimizing the variability caused by changes in raw waste and reducing the amount of sulfide precipitant required.

Operational Factors. Reliability: Alkaline chemical precipitation is highly reliable, although proper monitoring and control are required. Sulfide precipitation systems provide similar reliability.

Maintainability: The major maintenance needs involve periodic upkeep of monitoring equipment, automatic feeding equipment, mixing equipment, and other hardware. Removal of accumulated sludge is necessary for efficient operation of precipitation-sedimentation systems.

Solid Waste Aspects: Solids which precipitate out are removed in a subsequent treatment step. Ultimately, these solids require proper disposal.

Demonstration Status. Chemical precipitation of metal hydroxides is a classic waste treatment technology used by most industrial waste treatment systems. Chemical precipitation of metals in the carbonate form alone has been found to be feasible and is commercially used to permit metals recovery and water reuse. Full scale commercial sulfide precipitation units are in operation at numerous installations, including several plants in the coil coating category. As noted earlier, sedimentation to remove precipitates is discussed separately.

Use in Battery Manufacturing Plants. Chemical precipitation is used at 76 battery manufacturing. The quality of treatment provided, however, is variable. A review of collected data and on-site observations reveals that control of system parameters is often poor. Where precipitates are removed by clarification, retention times are likely to be short and cleaning and maintenance questionable. Similarly, pH control is frequently inadequate. As a result of these factors, effluent performance at battery plants nominally practicing the same wastewater treatment is observed to vary widely.

Chemical Reduction Of Chromium

Description of the Process. Reduction is a chemical reaction in which electrons are transferred to the chemical being reduced from the chemical initiating the transfer (the reducing agent). Sulfur dioxide, sodium bisulfite, sodium metabisulfite, and ferrous sulfate form strong reducing agents in aqueous solution and are often used in industrial waste treatment facilities for the reduction of hexavalent chromium to the trivalent form. The reduction allows removal of chromium from solution in conjunction with other metallic salts by alkaline precipitation. Hexavalent chromium is not precipitated as the hydroxide.

Gaseous sulfur dioxide is a widely used reducing agent and provides a good example of the chemical reduction process. Reduction using other reagents is chemically similar. The reactions involved may be illustrated as follows:

$$3 \; SO_2 + 3 \; H_2O \qquad\qquad 3 \; H_2SO_3$$

$$3 \; H_2SO_3 + 2H_2CrO_4 \qquad\qquad Cr_2(SO_4)_3 + 5 \; H_2O$$

The above reaction is favored by low pH. A pH of from 2 to 3 is normal for situations requiring complete reduction. At pH levels above 5, the reduction rate is slow. Oxidizing agents such as dissolved oxygen and ferric iron interfere with the reduction process by consuming the reducing agent.

A typical treatment consists of 45 minutes retention in a reaction tank. The reaction tank has an electronic recorder-controller device to control process conditions with respect to pH and oxidation reduction potential (ORP). Gaseous sulfur dioxide is metered to the reaction tank to maintain the ORP within the range of 250 to 300 millivolts. Sulfuric acid is added to maintain a pH level of from 1.8 to 2.0. The reaction tank is equipped with a propeller agitator designed to provide approximately one turnover per minute. Figure VII-30 (Page 600) shows a continuous chromium reduction system.

Application and Performance. Chromium reduction is used in battery manufacturing for treating chromium containing cell wash solutions and heat paper production wastewater. Chromium reduction is usually used to treat electroplating rinse waters, but may also be used in battery manufacturing plants. A study of an operational waste treatment facility chemically reducing hexavalent chromium has shown that a 99.7 percent reduction efficiency is easily achieved. Final concentrations of 0.05 mg/1 are readily attained, and concentrations of 0.01 mg/1 are considered to be attainable by properly maintained and operated equipment.

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Advantages and Limitations. The major advantage of chemical reduction to destroy hexavalent chromium is that it is a fully proven technology based on many years of experience. Operation at ambient conditions results in minimal energy consumption, and the process, especially when using sulfur dioxide, is well suited to automatic control. Furthermore, the equipment is readily obtainable from many suppliers, and operation is straightforward.

One limitation of chemical reduction of hexavalent chromium is that for high concentrations of chromium, the cost of treatment chemicals may be prohibitive. When this situation occurs, other treatment techniques are likely to be more economical. Chemical interference by oxidizing agents is possible in the treatment of mixed wastes, and the treatment itself may introduce pollutants if not properly controlled. Storage and handling of sulfur dioxide is somewhat hazardous.

Operational Factors. Reliability: Maintenance consists of periodic removal of sludge, the frequency of which is a function of the input concentrations of detrimental constituents.

Solid Waste Aspects: Pretreatment to eliminate substances which will interfere with the process may often be necessary. This process produces trivalent chromium which can be controlled by further treatment. There may, however, be small amounts of sludge collected due to minor shifts in the solubility of the contaminants. This sludge can be processed by the main sludge treatment equipment.

Demonstration Status. The reduction of chromium waste by sulfur dioxide or sodium bisulfite is a classic process and is used by numerous plants which have hexavalent chromium compounds in wastewaters from operations such as electroplating and noncontact cooling.

Cyanide Precipitation

Cyanide precipitation, although a method for treating cyanide in wastewaters, does not destroy cyanide. The cyanide is retained in the sludge that is formed. Reports indicate that during exposure to sunlight the cyanide complexes can break down and form free cyanide. For this reason the sludge from this treatment method must be disposed of carefully.

Cyanide may be precipitated and settled out of wastewaters by the addition of zinc sulfate or ferrous sulfate. In the presence of iron, cyanide will form extremely stable cyanide complexes. The addition of zinc sulfate or ferrous sulfate forms zinc ferrocyanide or ferro and ferricyanide complexes.

Adequate removal of the precipitated cyanide requires that the pH must be kept at 9.0 and an appropriate retention time be maintained. A study has shown that the formation of the complex is very dependent on pH. At pH's of 8 and 10 the residual cyanide concentrations measured are twice those of the same reaction carried out at a pH of 9. Removal efficiencies also depend heavily on the retention time allowed. The formation of the complexes takes place rather slowly. Depending upon the excess amount of zinc sulfate or ferrous sulfate added, at least a 30 minute retention time should be allowed for the formation of the cyanide complex before continuing on to the clarification stage.

One experiment with an initial concentration of 10 mg/l of cyanide showed that (98%) of the cyanide was complexed ten minutes after the addition of ferrous sulfate at twice the theoretical amount necessary. Interference from other metal ions, such as cadmium, might result in the need for longer retention times.

Table VII-7 presents data from three coil coating plants.

TABLE VII-7

CONCENTRATION OF TOTAL CYANIDE
(mg/l)

Plant	Method	In	Out
1057	$FeSO_4$	2.57	0.024
		2.42	0.015
		3.28	0.032
33056	$FeSO_4$	0.14	0.09
		0.16	0.09
12052	$ZnSO_4$	0.46	0.14
		0.12	0.06
Mean			0.07

The concentrations are those of the stream entering and leaving the treatment system. Plant 1057 allowed a 27 minute retention time for the formation of the complex. The retention time for the other plants is not known. The data suggest that over a wide range of cyanide concentration in the raw waste, the concentration of cyanide can be reduced in the effluent stream to under 0.15 mg/l.

Application and Performance. Cyanide precipitation can be used when cyanide destruction is not feasible because of the presence of cyanide complexes which are difficult to destroy. Effluent concentrations of cyanide well below 0.15 mg/l are possible.

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Advantages and Limitations. Cyanide precipitation is an inexpensive method of treating cyanide. Problems may occur when metal ions interfere with the formation of the complexes.

Granular Bed Filtration

Filtration occurs in nature as the surface ground waters are cleansed by sand. Silica sand, anthracite coal, and garnet are common filter media used in water treatment plants. These are usually supported by gravel. The media may be used singly or in combination. The multimedia filters may be arranged to maintain relatively distinct layers by virtue of balancing the forces of gravity, flow, and bouyancy on the individual particles. This is accomplished by selecting appropriate filter flow rates (gpm/sq-ft), media grain size, and density.

Granular bed filters may be classified in terms of filtration rate, filter media, flow pattern, or method of pressurization. Traditional rate classifications are slow sand, rapid sand, and high rate mixed media. In the slow sand filter, flux or hydraulic loading is relatively low, and removal of collected solids to clean the filter is therefore relatively infrequent. The filter is often cleaned by scraping off the inlet face (top) of the sand bed. In the higher rate filters, cleaning is frequent and is accomplished by a periodic backwash, opposite to the direction of normal flow.

A filter may use a single medium such as sand or diatomaceous earth, but dual and mixed (multiple) media filters allow higher flow rates and efficiencies. The dual media filter usually consists of a fine bed of sand under a coarser bed of anthracite coal. The coarse coal removes most of the influent solids, while the fine sand performs a polishing function. At the end of the backwash, the fine sand settles to the bottom because it is denser than the coal, and the filter is ready for normal operation. The mixed media filter operates on the same principle, with the finer, denser media at the bottom and the coarser, less dense media at the top. The usual arrangement is garnet at the bottom (outlet end) of the bed, sand in the middle, and anthracite coal at the top. Some mixing of these layers occurs and is, in fact, desirable.

The flow pattern is usually top-to-bottom, but other patterns are sometimes used. Upflow filters are sometimes used, and in a horizontal filter the flow is horizontal. In a biflow filter, the influent enters both the top and the bottom and exits laterally. The advantage of an upflow filter is that with an upflow backwash the particles of a single filter medium are distributed and maintained in the desired coarse-to-fine (bottom-to-top) arrangement. The disadvantage is that the bed tends to become fluidized, which ruins

filtration efficiency. The biflow design is an attempt to overcome this problem.

The classic granular bed filter operates by gravity flow; however, pressure filters are fairly widely used. They permit higher solids loadings before cleaning and are advantageous when the filter effluent must be pressurized for further downstream treatment. In addition, pressure filter systems are often less costly for low to moderate flow rates.

Figure VII-14 depicts a high rate, dual media, gravity downflow granular bed filter, with self-stored backwash. Both filtrate and backwash are piped around the bed in an arrangement that permits gravity upflow of the backwash, with the stored filtrate serving as backwash. Addition of the indicated coagulant and polyelectrolyte usually results in a substantial improvement in filter performance.

Auxiliary filter cleaning is sometimes employed in the upper few inches of filter beds. This is conventionally referred to as surface wash and is accomplished by water jets just below the surface of the expanded bed during the backwash cycle. These jets enhance the scouring action in the bed by increasing the agitation.

An important feature for successful filtration and backwashing is the underdrain. This is the support structure for the bed. The underdrain provides an area for collection of the filtered water without clogging from either the filtered solids or the media grains. In addition, the underdrain prevents loss of the media with the water, and during the backwash cycle it provides even flow distribution over the bed. Failure to dissipate the velocity head during the filter or backwash cycle will result in bed upset and the need for major repairs.

Several standard approaches are employed for filter underdrains. The simplest one consists of a parallel porous pipe imbedded under a layer of coarse gravel and manifolded to a header pipe for effluent removal. Other approaches to the underdrain system are known as the Leopold and Wheeler filter bottoms. Both of these incorporate false concrete bottoms with specific porosity configurations to provide drainage and velocity head dissipation.

Filter system operation may be manual or automatic. The filter backwash cycle may be on a timed basis, a pressure drop basis with a terminal value which triggers backwash, or a solids carryover basis from turbidity monitoring of the outlet stream. All of these schemes have been used successfully.

Application and Performance. Wastewater treatment plants often use granular bed filters for polishing after clarification, sedimentation, or other similar operations. Granular bed filtration thus has potential application to nearly all industrial plants. Chemical additives which enhance the upstream treatment equipment may or may not be compatible with or enhance the filtration process. Normal operating flow rates for various types of filters are as follows:

Slow Sand	2.04 - 5.30 l/sq m-hr
Rapid Sand	40.74 - 51.48 l/sq m-hr
High Rate Mixed Media	81.48 - 122.22 l/sq m-hr

Suspended solids are commonly removed from wastewater streams by filtering through a deep 0.3-0.9 m (1-3 feet) granular filter bed. The porous bed formed by the granular media can be designed to remove practically all suspended particles. Even colloidal suspensions (roughly 1 to 100 microns) are adsorbed on the surface of the media grains as they pass in close proximity in the narrow bed passages.

Properly operated filters following some pretreatment to reduce suspended solids below 200 mg/l should produce water with less than 10 mg/l TSS. For example, multimedia filters produced the effluent qualities shown in Table VII-8 below.

Table VII-8

Multimedia Filter Performance

Plant ID #	TSS Effluent Concentration, mg/l
06097	0.0, 0.0, 0.5
13924	1.8, 2.2, 5.6, 4.0, 4.0, 3.0, 2.2, 2.8
	3.0, 2.0, 5.6, 3.6, 2.4, 3.4
18538	1.0
30172	1.4, 7.0, 1.0
36048	2.1, 2.6, 1.5
mean	2.61

Advantages and Limitations. The principal advantages of granular bed filtration are its low initial and operating costs, reduced land requirements over other methods to achieve the same level of solids removal, and elimination of chemical additions to the discharge stream. However, the filter may require pretreatment if the solids level is high (over 100 mg/l). Operator training must be somewhat extensive due to the controls and periodic backwashing involved, and backwash must be stored and dewatered for economical disposal.

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Operational Factors. Reliability: The recent improvements in filter technology have significantly improved filtration reliability. Control systems, improved designs, and good operating procedures have made filtration a highly reliable method of water treatment.

Maintainability: Deep bed filters may be operated with either manual or automatic backwash. In either case, they must be periodically inspected for media attrition, partial plugging, and leakage. Where backwashing is not used, collected solids must be removed by shoveling, and filter media must be at least partially replaced.

Solid Waste Aspects: Filter backwash is generally recycled within the wastewater treatment system, so that the solids ultimately appear in the clarifier sludge stream for subsequent dewatering. Alternatively, the backwash stream may be dewatered directly or, if there is no backwash, the collected solids may be disposed of in a suitable landfill. In either of these situations there is a solids disposal problem similar to that of clarifiers.

Demonstration Status. Deep bed filters are in common use in municipal treatment plants. Their use in polishing industrial clarifier effluent is increasing, and the technology is proven and conventional. Granular bed filtration is used in several battery manufacturing plants. As noted previously, however, little data is available characterizing the effectiveness of filters presently in use within the industry.

Pressure Filtration

Pressure filtration works by pumping the liquid through a filter material which is impenetrable to the solid phase. The positive pressure exerted by the feed pumps or other mechanical means provides the pressure differential which is the principal driving force. Figure VII-15 (Page 585) represents the operation of one type of pressure filter.

A typical pressure filtration unit consists of a number of plates or trays which are held rigidly in a frame to ensure alignment and which are pressed together between a fixed end and a traveling end. On the surface of each plate is mounted a filter made of cloth or a synthetic fiber. The feed stream is pumped into the unit and passes through holes in the trays along the length of the press until the cavities or chambers between the trays are completely filled. The solids are then entrapped, and a cake begins to form on the surface of the filter material. The water passes through the fibers, and the solids are retained.

At the bottom of the trays are drainage ports. The filtrate is collected and discharged to a common drain. As the filter medium

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becomes coated with sludge, the flow of filtrate through the filter drops sharply, indicating that the capacity of the filter has been exhausted. The unit must then be cleaned of the sludge. After the cleaning or replacement of the filter media, the unit is again ready for operation.

Application and Performance. Pressure filtration is used in battery manufacturing for sludge dewatering and also for direct removal of precipitated and other suspended solids from wastewater.

Because dewatering is such a common operation in treatment systems, pressure filtration is a technique which can be found in many industries concerned with removing solids from their waste stream.

In a typical pressure filter, chemically preconditioned sludge detained in the unit for one to three hours under pressures varying from 5 to 13 atmospheres exhibited final solids content between 25 and 50 percent.

Advantages and Limitations. The pressures which may be applied to a sludge for removal of water by filter presses that are currently available range from 5 to 13 atmospheres. As a result, pressure filtration may reduce the amount of chemical pretreatment required for sludge dewatering. Sludge retained in the form of the filter cake has a higher percentage of solids than that from centrifuge or vacuum filter. Thus, it can be easily accommodated by materials handling systems.

As a primary solids removal technique, pressure filtration requires less space than clarification and is well suited to streams with high solids loadings. The sludge produced may be disposed without further dewatering, but the amount of sludge is increased by the use of filter precoat materials (usually diatomaceous earth). Also, cloth pressure filters often do not achieve as high a degree of effluent clarification as clarifiers or granular media filters.

Two disadvantages associated with pressure filtration in the past have been the short life of the filter cloths and lack of automation. New synthetic fibers have largely offset the first of these problems. Also, units with automatic feeding and pressing cycles are now available.

For larger operations, the relatively high space requirements, as compared to those of a centrifuge, could be prohibitive in some situations.

Operational Factors. Reliability: With proper pretreatment, design, and control, pressure filtration is a highly dependable system.

Maintainability: Maintenance consists of periodic cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the system. If the removal of the sludge cake is not automated, additional time is required for this operation.

Solid Waste Aspects: Because it is generally drier than other types of sludges, the filter sludge cake can be handled with relative ease. The accumulated sludge may be disposed by any of the accepted procedures depending on its chemical composition. The levels of toxic metals present in sludge from treating battery wastewater necessitate proper disposal.

Demonstration Status. Pressure filtration is a commonly used technology in a great many commercial applications. Pressure filtration is used in six battery manufacturing plants.

Settling

Settling is a process which removes solid particles from a liquid matrix by gravitational force. This is done by reducing the velocity of the feed stream in a large effected by reducing the velocity of the feed stream in a large volume tank or lagoon so that gravitational settling can occur. Figure VII-13 (Page 583) shows two typical settling devices.

Settling is often preceded by chemical precipitation which converts dissolved pollutants to solid form and by coagulation which enhances settling by coagulating suspended precipitates into larger, faster settling particles.

If no chemical pretreatment is used, the wastewater is fed into a tank or lagoon where it loses velocity and the suspended solids are allowed to settle out. Long retention times are generally required. Accumulated sludge can be collected either periodically or continuously and either manually or mechanically. Simple settling, however, may require excessively large catchments, and long retention times (days as compared with hours) to achieve high removal efficiencies. Because of this, addition of settling aids such as alum or polymeric flocculants is often economically attractive.

In practice, chemical precipitation often precedes settling, and inorganic coagulants or polyelectrolytic flocculants are usually added as well. Common coagulants include sodium sulfate, sodium aluminate, ferrous or ferric sulfate, and ferric chloride. Organic

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polyelectrolytes vary in structure, but all usually form larger floc particles than coagulants used alone.

Following this pretreatment, the wastewater can be fed into a holding tank or lagoon for settling, but is more often piped into a clarifier for the same purpose. A clarifier reduces space requirements, reduces retention time, and increases solids removal efficiency. Conventional clarifiers generally consist of a circular or rectangular tank with a mechanical sludge collecting device or with a sloping funnel-shaped bottom designed for sludge collection. In advanced settling devices inclined plates, slanted tubes, or a lamellar network may be included within the clarifier tank in order to increase the effective settling area, increasing capacity. A fraction of the sludge stream is often recirculated to the inlet, promoting formation of a denser sludge.

Application and Performance. Settling and clarification are used in the battery manufacturing category to remove precipitated metals. Settling can be used to remove most suspended solids in a particular waste stream; thus it is used extensively by many different industrial waste treatment facilities. Because most metal ion pollutants are readily converted to solid metal hydroxide precipitates, settling is of particular use in those industries associated with metal production, metal finishing, metal working, and any other industry with high concentrations of metal ions in their wastewaters. In addition to toxic metals, suitably precipitated materials effectively removed by settling include aluminum, iron, manganese, cobalt, antimony, beryllium, molybdenum, fluoride, phosphate, and many others.

A properly operating settling system can efficiently remove suspended solids, precipitated metal hydroxides, and other impurities from wastewater. The performance of the process depends on a variety of factors, including the density and particle size of the solids, the effective charge on the suspended particles, and the types of chemicals used in pretreatment. The site of flocculant or coagulant addition also may significantly influence the effectiveness of clarification. If the flocculant is subjected to too much mixing before entering the clarifier, the complexes may be sheared and the settling effectiveness diminished. At the same time, the flocculant must have sufficient mixing and reaction time in order for effective set-up and settling to occur. Plant personnel have observed that the line or trough leading into the clarifier is often the most efficient site for flocculant addition. The performance of simple settling is a function of the retention time, particle size and density, and the surface area of the basin.

The data displayed in Table VII-9 indicate suspended solids removal efficiencies in settling systems.

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TABLE VII-9
PERFORMANCE OF SAMPLED SETTLING SYSTEMS

PLANT ID	SETTLING DEVICE	SUSPENDED SOLIDS CONCENTRATION (mg/l)					
		Day 1		Day 2		Day 3	
		In	Out	In	Out	In	Out
01057	Lagoon	54	6	56	6	50	5
09025	Clarifier Settling Ponds	1100	9	1900	12	1620	5
11058	Clarifier	451	17	-	-	-	-
12075	Settling Pond	284	6	242	10	502	14
19019	Settling Tank	170	1	50	1	-	-
33617	Clarifier & Lagoon	-	-	1662	16	1298	4
40063	Clarifier	4390	9	3595	12	2805	13
44062	Clarifier	182	13	118	14	174	23
46050	Settling Tank	295	10	42	10	153	8

The mean effluent TSS concentration obtained by the plants shown in Table VII-9 is 10.1 mg/l. Influent concentrations averaged 838 mg/l. The maximum effluent TSS value reported is 23 mg/l. These plants all use alkaline pH adjustment to precipitate metal hydroxides, and most add a coagulant or flocculant prior to settling.

Advantages and Limitations. The major advantage of simple settling is its simplicity as demonstrated by the gravitational settling of solid particulate waste in a holding tank or lagoon. The major problem with simple settling is the long retention time necessary to achieve complete settling, especially if the specific gravity of the suspended matter is close to that of water. Some materials cannot be practically removed by simple settling alone.

Settling performed in a clarifier is effective in removing slow-settling suspended matter in a shorter time and in less space than a simple settling system. Also, effluent quality is often better from a clarifier. The cost of installing and maintaining a clarifier, however, is substantially greater than the costs associated with simple settling.

Inclined plate, slant tube, and lamella settlers have even higher removal efficiencies than conventional clarifiers, and greater capacities per unit area are possible. Installed costs for these advanced clarification systems are claimed to be one half the cost of conventional systems of similar capacity.

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Operational Factors. Reliability: Settling can be a highly reliable technology for removing suspended solids. Sufficient retention time and regular sludge removal are important factors affecting the reliability of all settling systems. Proper control of pH adjustment, chemical precipitation, and coagulant or flocculant addition are additional factors affecting settling efficiencies in systems (frequently clarifiers) where these methods are used.

Those advanced settlers using slanted tubes, inclined plates, or a lamellar network may require pre-screening of the waste in order to eliminate any fibrous materials which could potentially clog the system. Some installations are especially vulnerable to shock loadings, as by storm water runoff, but proper system design will prevent this.

Maintainability: When clarifiers or other advanced settling devices are used, the associated system utilized for chemical pretreatment and sludge dragout must be maintained on a regular basis. Routine maintenance of mechanical parts is also necessary. Lagoons require little maintenance other than periodic sludge removal.

Demonstration Status. Settling represents the typical method of solids removal and is employed extensively in industrial waste treatment. The advanced clarifiers are just beginning to appear in significant numbers in commercial applications. Sedimentation or clarification is used in many battery manufacturing plants as shown below.

Settling Device	No. Plants
Settling Tanks	55
Clarifier	13
Tube or Plate Settler	1
Lagoon	10

Settling is used both as part of end-of-pipe treatment and within the plant to allow recovery of process solutions and raw materials. As examples, settling tanks are commonly used on pasting waste streams in lead acid battery manufacture to allow recovery of process water and paste solids, and settling sump tanks are used to recover nickel and cadmium in nickel cadmium battery manufacture.

Skimming

Pollutants with a specific gravity less than water will often float unassisted to the surface of the wastewater. Skimming removes these floating wastes. Skimming normally takes place in a tank designed to allow the floating debris to rise and remain on the surface, while the liquid flows to an outlet located below the floating layer. Skimming

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devices are therefore suited to the removal of non-emulsified oils from raw waste streams. Common skimming mechanisms include the rotating drum type, which picks up oil from the surface of the water as it rotates. A doctor blade scrapes oil from the drum and collects it in a trough for disposal or reuse. The water portion is allowed to flow under the rotating drum. Occasionally, an underflow baffle is installed after the drum; this has the advantage of retaining any floating oil which escapes the drum skimmer. The belt type skimmer is pulled vertically through the water, collecting oil which is scraped off from the surface and collected in a drum. Gravity separators, such as the API type, utilize overflow and underflow baffles to skim a floating oil layer from the surface of the wastewater. An overflow-underflow baffle allows a small amount of wastewater (the oil portion) to flow over into a trough for disposition or reuse while the majority of the water flows underneath the baffle. This is followed by an overflow baffle, which is set at a height relative to the first baffle such that only the oil bearing portion will flow over the first baffle during normal plant operation. A diffusion device, such as a vertical slot baffle, aids in creating a uniform flow through the system and increasing oil removal efficiency.

Application and Performance. Oil skimming is used in battery manufacture to remove free oil used as a preservative or forming lubricant for various metal battery parts. Another source of oil is lubricants for drive mechanisms and other machinery contacted by process water. Skimming is applicable to any waste stream containing pollutants which float to the surface. It is commonly used to remove free oil, grease, and soaps. Skimming is often used in conjunction with air flotation or clarification in order to increase its effectiveness.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Larger, more buoyant particles require less retention time than smaller particles. Thus, the efficiency also depends on the composition of the waste stream. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending on the wastewater characteristics.

API or other gravity-type separators tend to be more suitable for use where the amount of surface oil flowing through the system is consistently significant. Drum and belt type skimmers are applicable to waste streams which evidence smaller amounts of floating oil and where surges of floating oil are not a problem. Using an API separator system in conjunction with a drum type skimmer would be a very effective method of removing floating contaminants from non-emulsified oily waste streams. Sampling data shown below illustrate the capabilities of the technology with both extremely high and moderate oil influent levels.

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Table VII-10

SKIMMING PERFORMANCE

Oil & Grease
mg/l

Plant	Skimmer Type	In	Out
06058	API	224,669	17.9
06058	Belt	19.4	8.3

Based on data from installations in a variety of manufacturing plants, it is determined that effluent oil levels may be reliably reduced below 10 mg/l with moderate influent concentrations. Very high concentrations of oil such as the 22 percent shown above may require two step treatment to achieve this level.

Skimming which removes oil may also be used to remove base levels of organics. Plant sampling data show that many organic compounds tend to be removed in standard wastewater treatment equipment. Oil separation not only removes oil but also organics that are more soluble in oil than in water. Clarification removes organic solids directly and probably removes dissolved organics by adsorption on inorganic solids.

The source of these organic pollutants is not always known with certainty, although in the copper and copper alloy industry they seem to derive mainly from various process lubricants. They are also sometimes present in the plant water supply, as additives to proprietary formulations of cleaners, or due to leaching from plastic lines and other materials.

A study of priority organic compounds commonly found in copper and copper alloy waste streams indicated that incidental removal of these compounds often occurs as a result of oil removal or clarification processes. When all organics analyses from visited plants are considered, removal of organic compounds by other waste treatment technologies appears to be marginal in many cases. However, when only raw waste concentrations of 0.05 mg/l or greater are considered incidental organics removal becomes much more apparent. Lower values, those less than 0.05 mg/l, are much more subject to analytical variation, while higher values indicate a significant presence of a given compound. When these factors are taken into account, analysis data indicate that most clarification and oil removal treatment systems remove significant amounts of the organic compounds present in the raw waste. The API oil-water separation system and the thermal emulsion breaker performed notably in this regard, as shown in the following table (all values in mg/l).

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TABLE VII-11

TRACE ORGANIC REMOVAL BY SKIMMING

	API (06058)		TEB (04086)	
	Inf.	Eff.	Inf.	Eff.
Oil & Grease	225,000	14.6	2,590	10.3
Chloroform	.023	.007	0	0
Methylene Chloride	.013	.012	0	0
Naphthalene	2.31	.004	1.83	.003
N-nitrosodiphenylamine	59.0	.182	–	–
Bis-2-ethylhexylphthalate	11.0	.027	1.55	.018
Diethyl phthalate	–	–	.017	.005
Butylbenzylphthalate	.005	.002	–	–
Di-n-octyl phthalate	.019	.002	–	–
Anthracene – phenanthrene	16.4	.014	.144	.002
Toluene	.02	.012	–	–

The unit operation most applicable to removal of trace priority organics is adsorption, and chemical oxidation is another possibility. Biological degradation is not generally applicable because the organics are not present in sufficient concentration to sustain a biomass and because most of the organics are resistant to biodegradation.

Advantages and Limitations. Skimming as a pretreatment is effective in removing naturally floating waste material. It also improves the performance of subsequent downstream treatments.

Many pollutants, particularly dispersed or emulsified oil, will not float "naturally" but require additional treatments. Therefore, skimming alone may not remove all the pollutants capable of being removed by air flotation or other more sophisticated technologies.

Operational Factors. Reliability: Because of its simplicity, skimming is a very reliable technique.

Maintainability: The skimming mechanism requires periodic lubrication, adjustment, and replacement of worn parts.

Solid Waste Aspects: The collected layer of debris must be disposed of by contractor removal, landfill, or incineration. Because relatively large quantities of water are present in the collected wastes, incineration is not always a viable disposal method.

Demonstration Status. Skimming is a common operation utilized extensively by industrial waste treatment systems. Oil skimming is used in seven battery manufacturing plants.

MAJOR TECHNOLOGY EFFECTIVENESS

The performance of individual treatment technologies was presented above. Performance of operating systems is discussed here. Two different systems are considered: L&S (hydroxide precipitation and sedimentation or lime and settle) and LS&F (hydroxide precipitation, sedimentation and filtration or lime, settle, and filter). Subsequently, an analysis of effectiveness of such systems is made to develop one-day maximum and thirty-day average concentration levels to be used in regulating pollutants. Evaluation of the L&S and the LS&F systems is carried out on the assumption that chemical reduction of chromium, cyanide precipitation, and oil skimming are installed and operating properly where appropriate.

L&S Performance

Sampling data was analyzed from fifty-five industrial plants which use chemical precipitation as a waste treatment technology. These plants include the electroplating, mechanical products, metal finishing, coil coating, pprcelain enameling, battery manufacturing, copper forming and aluminum forming categories. All of the plants employ pH adjustment and hydroxide precipitation using lime or caustic, followed by settling (tank, lagoon or clarifier) for solids removal. Most also add a coagulant or flocculant prior to solids removal. No sample analyses were included where effluent TSS levels exceeded 50 mg/l or where the effluent pH fell below 7.0. This was done to exclude any data which represented clearly inadequate operation of the treatment system. These data are derived from a variety of industrial manufacturing operations which have wastewater relatively similar to battery manufacturing wastewaters. Plots were made of the available data for eight metal pollutants showing effluent concentration vs. raw waste concentration (Figures VII-3 - VII-11) (Pages 573-581) for each parameter. Table VII-12 summarizes data shown in Figures VII-3 through VII-11, tabulating for each pollutant of interest the number of data points and average of observed values. Generally accepted design values (GADV) for these metals are also shown in Table VII-12.

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TABLE VII-12

Hydroxide Precipitation - Settling (L&S) Performance

Specific metal	No. data points	Observed Average	GADV
Cd	38	0.013	0.02
Cr	64	0.47	0.2
Cu	74	0.61	0.2
Pb	85	0.034	0.02
Ni	61	0.84	0.2
Zn	69	0.40	0.5
Fe	88	0.57	0.3
Mn	20	0.11	0.3
P	44	4.08	-

A number of other pollutant parameters were considered with regard to the performance of hydroxide precipitation-settling treatment systems in removing them from industrial wastewater. Sampling data for most of these parameters is scarce, so published sources were consulted for the determination of average and 24-hour maximum concentrations. Sources consulted include text books, periodicals and EPA publications as listed in Section XV as well as applicable sampling data.

The available data indicate that the concentrations shown in Table VII-13 are reliably attainable with hydroxide precipitation and settling. The precipitation of silver appears to be accomplished by alkaline chloride precipitation and adequate chloride ions must be available for this reaction to occur.

TABLE VII-13
Hydroxide Precipitation-Settling (L&S) Performance
ADDITIONAL PARAMETERS

Parameter (mg/l)	Average	24-Hour Maximum
Sb	0.05	0.50
As	0.05	0.50
Be	0.3	1.0
Hg	0.03	0.10
Se	0.01	0.10
Ag	0.10	0.30
Al	0.2	0.55
Co	0.07	0.50
F	15	30
Ti	0.01	0.10

LS&F Performance

Tables VII-6 and VII-7 show long term data from two plants which have well operated precipitation-settling treatment followed by filtration. The wastewaters from both plants contain pollutants from metals processing and finishing operations (multi-category). Both plants reduce hexavalent chromium before neutralizing and precipitating metals with lime. A clarifier is used to remove much of the solids load and a filter is used to "polish" or complete removal of suspended solids. Plant A uses pressure filtration, while Plant B uses a rapid sand filter.

Raw waste data was collected only occasionally at each facility and the raw waste data is presented as an indication of the nature of the wastewater treated. Data from plant A was received as a statistical summary and is presented as received. Raw laboratory data was collected at plant B and reviewed for spurious points and discrepancies. The method of treating the data base is discussed below under lime, settle, and filter treatment effectiveness.

TABLE VII-14

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant A

Parameters	No Pts.	Range mg/l	Mean + std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	47	0.015 - 0.13	0.045 ±0.029	0.10
Cu	12	0.01 - 0.03	0.019 ±0.006	0.03
Ni	47	0.08 - 0.64	0.22 ±0.13	0.48
Zn	47	0.08 - 0.53	0.17 ±0.09	0.35
Fe				
For 1978-Treated Wastewater				
Cr	47	0.01 - 0.07	0.06 ±0.10	0.26
Cu	28	0.005 - 0.055	0.016 ±0.010	0.04
Ni	47	0.10 - 0.92	0.20 ±0.14	0.48
Zn	47	0.08 - 2.35	0.23 ±0.34	0.91
Fe	21	0.26 - 1.1	0.49 ±0.18	0.85
Raw Waste				
Cr	5	32.0 - 72.0		
Cu	5	0.08 - 0.45		
Ni	5	1.65 - 20.0		
Zn	5	33.2 - 32.0		
Fe	5	10.0 - 95.0		

TABLE VII-15

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant B

Parameters	No Pts.	Range mg/l	Mean + std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	175	0.0 - 0.40	0.068 +0.075	0.22
Cu	176	0.0 - 0.22	0.024 +0.021	0.07
Ni	175	0.01 - 1.49	0.219 +0.234	0.69
Zn	175	0.01 - 0.66	0.054 +0.064	0.18
Fe	174	0.01 - 2.40	0.303 +0.398	1.10
TSS	2	1.00 - 1.00		
For 1978-Treated Wastewater				
Cr	144	0.0 - 0.70	0.059 +0.088	0.24
Cu	143	0.0 - 0.23	0.017 +0.020	0.06
Ni	143	0.0 - 1.03	0.147 +0.142	0.43
Zn	131	0.0 - 0.24	0.037 +0.034	0.11
Fe	144	0.0 - 1.76	0.200 +0.223	0.47
Total 1974-1979-Treated Wastewater				
Cr	1288	0.0 - 0.56	0.038 +0.055	0.15
Cu	1290	0.0 - 0.23	0.011 +0.016	0.04
Ni	1287	0.0 - 1.88	0.184 +0.211	0.60
Zn	1273	0.0 - 0.66	0.035 +0.045	0.13
Fe	1287	0.0 - 3.15	0.402 +0.509	1.42
Raw Waste				
Cr	3	2.80 - 9.15	5.90	
Cu	3	0.09 - 0.27	0.17	
Ni	3	1.61 - 4.89	3.33	
Zn	2	2.35 - 3.39		
Fe	3	3.13 -35.9	22.4	
TSS	2	177 -446		

These data are presented to demonstrate the performance of precipitation-settling-filtration (LS&F) technology under actual operating conditions and over a long period of time.

It should be noted that the iron content of the raw waste of both plants is high. This results in coprecipitation of toxic metals with iron, a process sometimes called ferrite precipitation. Ferrite precipitation using high-calcium lime for pH control yields the

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results shown above. Plant operating personnel indicate that this chemical treatment combination (sometimes with polymer assisted coagulation) generally produces better and more consistant metals removal than other combinations of sacrificial metal ions and alkalis.

Analysis of Treatment System Effectiveness

Data were presented in Tables VII-14 and VII-15 showing the effectiveness of L&S and LS&F technologies when applied to battery manufacturing or essentially similar wastewaters. An analysis of these data has been made to develop one-day-maximum and 30-day-average values for use in establishing effluent limitations and standards. Several approaches were investigated and considered. These approaches are briefly discussed and the average (mean), 30-day average, and maximum (1-day) values are tabulated for L&S and LS&F technologies.

L&S technology data are presented in Figures VII-3 through VII-11 (Page 573-581) and are summarized in Table VII-12. The data summary shows observed average values. To develop the required regulatory base concentrations from these data, variability factors were transferred from electroplating pretreatment (Electroplating Pretreatment Development Document, 440/1-79/003, page 397). and applied to the observed average values. One-day-maximum and 30-day-average values were calculated and are presented in Table VII-16.

For the pollutants for which no observed one-day variability factor values are available the average variability factor from electroplating one-day values (i.e. 3.18) was used to calculate one-day maximum regulatory values from average (mean) values presented in Tables VII-12 and VII-13. Likewise, the average variability factor from electroplating 30-day-average variability factors (i.e. 1.3) was used to calculate 30-day average regulatory values. These calculated one-day maximums and 30-day averages, to be used for regulations, are presented in Table VII-16.

Table - A

Variability Factors of Lime and Settle (L&S) Technology

Metal	one-day maximum	30 day average
	electro-plating	electro-plating
Cd	2.9	1.3
Cr	3.9	1.4
Cu	3.2	1.3
Pb	2.9	1.3

Ni	2.9	1.3
Zn	3.0	1.3
Fe	3.81	1.3
Mean	3.18	1.3

LS&F technology data are presented in Tables VII-14 and VII-15. These data represent two operating plants (A and B) in which the technology has been installed and operated for some years. Plant A data was received as a statistical summary and is presented without change. Plant B data was received as raw laboratory analysis data. Discussions with plant personnel indicated that operating experiments and changes in materials and reagents and occasional operating errors had occured during the data collection period. No specific information was available on those variables. To sort out high values probably caused by methodological factors from random statistical variability, or data noise, the plant B data were analyzed. For each of four pollutants (chromium, nickel, zinc, and iron), the mean and standard deviation (sigma) were calculated for the entire data set. A data day was removed from the complete data set when any individual pollutant concentration for that day exceeded the sum of the mean plus three sigma for that pollutant. Fifty-one data days were eliminated by this method.

Another approach was also used as a check on the above method of eliminating certain high values. The minimum values of raw wastewater concentrations from Plant B for the same four pollutants were compared to the total set of values for the corresponding pollutants. Any day on which the pollutant concentration exceeded the minimum value selected from raw wastewater concentrations for that pollutant was discarded. Forty-five days of data were eliminated by that procedure. Forty-three days of data were eliminated by both procedures. Since common engineering practice (mean plus 3 sigma) and logic (treated waste should be less than raw waste) seem to coincide, the data base with the 51 spurious data days eliminated will be the basis for all further analysis. Range, mean, standard deviation and mean plus two standard deviations are shown in Tables VII-14 and VII-15 for Cr, Cu, Ni, Zn and Fe.

The Plant B data was separated into 1979, 1978, and total data base segments. With the statistical analysis from Plant A for 1978 and 1979 this in effect created five data sets in which there is some overlap between the individual years and total data sets from Plant B. By comparing these five parts it is apparent that they are quite similar and all appear to be from the same family of numbers. Selecting the greatest mean and greatest mean plus two standard deviations draws values from four of the five data bases. These values are displayed in the first two columns of Table VII-B and

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TABLE VII-16
Summary of Treatment Effectiveness

Pollutant Parameter	L&S Technology System			LS&F Technology System			Sulfide Precipitation Filtration		
	Mean	One Day Max.	Thirty Day Avg.	Mean	One Day Max.	Thirty Day Avg.	Mean	One Day Max.	Thirty Day Avg.
114 Sb	0.05	0.16	0.07	0.033	0.11	0.043			
115 As	0.05	0.16	0.07	0.033	0.11	0.043			
117 Be	0.3	0.96	0.39	0.20	0.63	0.26			
118 Cd	0.02	0.06	0.03	0.014	0.044	0.018	0.01	0.032	0.013
119 Cr	0.47	1.83	0.66	0.07	0.27	0.10	0.05	0.16	0.065
120 Cu	0.61	1.95	0.79	0.41	1.31	0.53	0.05	0.16	0.065
121 CN	0.07	0.22	0.09	0.047	0.15	0.06			
122 Pb	0.034	0.10	0.05	0.034	0.10	0.044	0.01	0.032	0.013
123 Hg	0.03	0.10	0.04	0.02	0.063	0.026	0.03	0.095	0.039
124 Ni	0.84	1.44	1.09	0.22	0.64	0.29	0.05	0.16	0.065
125 Se	0.01	0.03	0.01	0.007	0.021	0.009			
126 Ag	0.1	0.32	0.13	0.007	0.21	0.087	0.05	0.16	0.065
128 Zn	0.5	1.5	0.65	0.23	0.69	0.30	0.01	0.032	0.013
Al	0.2	0.64	0.26	0.14	0.42	0.18			
Co	0.07	0.22	0.09	0.047	0.147	0.061			
F	15	47.7	19.5	10.0	31.5	13.0			
Fe	0.57	2.17	0.65	0.49	1.87	0.64			
Mn	0.11	0.35	0.14	0.079	0.23	0.095			
P	4.08	13.0	5.30	2.78	8.57	3.54			
Ti	0.01	0.03	0.01	0.007	0.021	0.009			
O&G	-	20.0	10.0		10.0	10.0			
TSS	10.1	35.0	25.0	2.6	15.0	10.0			

represent one approach to analysis of the LS&F data to obtain average (mean) and one-day maximum values for regulatory purposes.

The other candidates for regulatory values are presented in Table VII-B and were derived by multiplying the mean by the appropriate variability factor from electroplating (Table A). These values are the ones used for one-day maximum and 30-day average regulatory numbers.

Table - B

Analysis of Plant A and Plant B data

Composite Mean	Mean+ 2 sigma	Composite Mean X Plant B One Day Electpltg. Var.Fact.	Composite Mean X 30 day Electpltg. Var.Fact.
Cr 0.068	0.26	0.27	0.095
Cu 0.02	0.07	0.077	0.026
Ni 0.22	0.69	0.64	0.286
Zn 0.23	0.91	0.69	0.299
Fe 0.49	1.42	1.87	0.637

Concentration values for regulatory use are displayed in Table VII-16. Mean values for L&S were taken from Tables VII-12, VII-13, and the discussions following Tables VII-9, and VII-10. Thirty-day average and one-day maximum values for L&S were derived from means and variability factors as discussed earlier under L&S.

Copper levels achieved at Plants A and B are lower than believed to be generally achievable because of the high iron content of the raw wastewaters. Therefore, the mean concentration value achieved is not used; LS&F mean used is derived from the L&S technology.

The mean concentration of lead is not reduced from the L&S value because of the relatively high solubility of lead carbonate.

L&S cyanide mean levels shown in Table VII-7 are ratioed to one day maximum and 30 day average values using mean variability factors. LS&F mean cyanide is calculated by applying the ratios of removals L&S and LS&F as discussed previously for LS&F metals limitations.

The filter performance for removing TSS as shown in Table VII-8 yields a mean effluent concentration of 2.61 mg/l and calculates to a 30 day average of 5.58 mg/l; a one day maximum of 8.23. These calculated

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values more than amply support the classic values of 10 and 15, respectively, which are used for LS&F.

Mean values for LS&F for pollutants not already discussed are derived by reducing the L&S mean by one-third. The one-third reduction was established after examining the percent reduction in concentrations going from L&S to LS&F data for Cr, Ni, Zn, and TSS. The reductions were 85 percent, 74 percent, 54 percent, and 74 percent, respectively. The 33 percent reduction is conservative when compared to the smallest reduction for metals removals of more than 50 percent in going from L&S to LS&F.

The one-day maximum and 30-day average values for LS&F for pollutants for which data were not available were derived by multiplying the means by the average one-day and 30-day variability factors. Although iron was reduced in some LS&F operations, some facilities using that treatment introduce iron compounds to aid settling. Therefore, the value for iron at LS&F was held at the L&S level so as to not unduly penalize the operations which use the relatively less objectionable iron compounds to enhance removals of toxic metals.

MINOR TECHNOLOGIES

Several other treatment technologies were considered for possible application in BPT or BAT. These technologies are presented here with a full discussion for most of them. A few are described only briefly because of limited technical development.

Carbon Adsorption

The use of activated carbon to remove dissolved organics from water and wastewater is a long demonstrated technology. It is one of the most efficient organic removal processes available. This sorption process is reversible, allowing activated carbon to be regenerated for reuse by the application of heat and steam or solvent. Activated carbon has also proved to be an effective adsorbent for many toxic metals, including mercury. Regeneration of carbon which has adsorbed significant metals, however, may be difficult.

The term activated carbon applies to any amorphous form of carbon that has been specially treated to give high adsorption capacities. Typical raw materials include coal, wood, coconut shells, petroleum base residues and char from sewage sludge pyrolysis. A carefully controlled process of dehydration, carbonization, and oxidation yields a product which is called activated carbon. This material has a high capacity for adsorption due primarily to the large surface area available for adsorption, 500-1500 m^2/sq m resulting from a large number of internal pores. Pore sizes generally range from 10-100 angstroms in radius.

Activated carbon removes contaminants from water by the process of adsorption, or the attraction and accumulation of one substance on the surface of another. Activated carbon preferentially adsorbs organic compounds and, because of this selectivity, is particularly effective in removing organic compounds from aqueous solution.

Carbon adsorption requires pretreatment to remove excess suspended solids, oils, and greases. Suspended solids in the influent should be less than 50 mg/l to minimize backwash requirements; a downflow carbon bed can handle much higher levels (up to 2000 mg/l), but requires frequent backwashing. Backwashing more than two or three times a day is not desirable; at 50 mg/l suspended solids one backwash will suffice. Oil and grease should be less than about 10 mg/l. A high level of dissolved inorganic material in the influent may cause problems with thermal carbon reactivation (i.e., scaling and loss of activity) unless appropriate preventive steps are taken. Such steps might include pH control, softening, or the use of an acid wash on the carbon prior to reactivation.

Activated carbon is available in both powdered and granular form. An adsorption column packed with granular activated carbon is shown in Figure VII-26. Powdered carbon is less expensive per unit weight and may have slightly higher adsorption capacity, but it is more difficult to handle and to regenerate.

Application and Performance. Carbon adsorption is used to remove mercury from wastewaters. The removal rate is influenced by the mercury level in the influent to the adsorption unit. Removal levels found at three manufacturing facilities are:

Table VII-17

ACTIVATED CARBON PERFORMANCE (MERCURY)

Plant	Mercury levels - mg/l	
	In	Out
A	28.0	0.9
B	0.36	0.015
C	0.008	0.0005

In the aggregate these data indicate that very low effluent levels could be attained from any raw waste by use of multiple adsorption stages. This is characteristic of adsorption processes.

Isotherm tests have indicated that activated carbon is very effective in adsorbing 65 percent of the organic priority pollutants and is reasonably effective for another 22 percent. Specifically, for the organics of particular interest, activated carbon was very effective

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in removing 2,4-dimethylphenol, fluoranthene, isophorone, naphthalene, all phthalates, and phenanthrene. It was reasonably effective on 1,1,1-trichloroethane, 1,1-dichloroethane, phenol, and toluene. Table VII-18 (Page 601) summarizes the treatability effectiveness for most of the organic priority pollutants by activated carbon as compiled by EPA. Table VII-19 (Page 602) summarizes classes of organic compounds together with examples of organics that are readily adsorbed on carbon.

Advantages and Limitations. The major benefits of carbon treatment include applicability to a wide variety of organics, and high removal efficiency. Inorganics such as cyanide, chromium, and mercury are also removed effectively. Variations in concentration and flow rate are well tolerated. The system is compact, and recovery of adsorbed materials is sometimes practical. However, destruction of adsorbed compounds often occurs during thermal regeneration. If carbon cannot be thermally desorbed, it must be disposed of along with any adsorbed pollutants. The capital and operating costs of thermal regeneration are relatively high. Cost surveys show that thermal regeneration is generally economical when carbon usage exceeds about 1,000 lb/day. Carbon cannot remove low molecular weight or highly soluble organics. It also has a low tolerance for suspended solids, which must be removed to at least 50 mg/l in the influent water.

Operational Factors. Reliability: This system should be very reliable with upstream protection and proper operation and maintenance procedures.

Maintainability: This system requires periodic regeneration or replacement of spent carbon and is dependent upon raw waste load and process efficiency.

Solid Waste Aspects: Solid waste from this process is contaminated activated carbon that requires disposal. Carbon undergoes regeneration, reduces the solid waste problem by reducing the frequency of carbon replacement.

Demonstration Status. Carbon adsorption systems have been demonstrated to be practical and economical in reducing COD, BOD and related parameters in secondary municipal and industrial wastewaters; in removing toxic or refractory organics from isolated industrial wastewaters; in removing and recovering certain organics from wastewaters; and in the removing and some times recovering, of selected inorganic chemicals from aqueous wastes. Carbon adsorption is a viable and economic process for organic waste streams containing up to 1 to 5 percent of refractory or toxic organics. Its applicability for removal of inorganics such as metals has also been demonstrated.

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Centrifugation

Centrifugation is the application of centrifugal force to separate solids and liquids in a liquid-solid mixture or to effect concentration of the solids. The application of centrifugal force is effective because of the density differential normally found between the insoluble solids and the liquid in which they are contained. As a waste treatment procedure, centrifugation is applied to dewatering of sludges. One type of centrifuge is shown in Figure VII-17 (Page 587).

There are three common types of centrifuges: the disc, basket, and conveyor type. All three operate by removing solids under the influence of centrifugal force. The fundamental difference between the three types is the method by which solids are collected in and discharged from the bowl.

In the disc centrifuge, the sludge feed is distributed between narrow channels that are present as spaces between stacked conical discs. Suspended particles are collected and discharged continuously through small orifices in the bowl wall. The clarified effluent is discharged through an overflow weir.

A second type of centrifuge which is useful in dewatering sludges is the basket centrifuge. In this type of centrifuge, sludge feed is introduced at the bottom of the basket, and solids collect at the bowl wall while clarified effluent overflows the lip ring at the top. Since the basket centrifuge does not have provision for continuous discharge of collected cake, operation requires interruption of the feed for cake discharge for a minute or two in a 10 to 30 minute overall cycle.

The third type of centrifuge commonly used in sludge dewatering is the conveyor type. Sludge is fed through a stationary feed pipe into a rotating bowl in which the solids are settled out against the bowl wall by centrifugal force. From the bowl wall, they are moved by a screw to the end of the machine, at which point whey are discharged. The liquid effluent is discharged through ports after passing the length of the bowl under centrifugal force.

Application And Performance. Virtually all industrial waste treatment systems producing sludge can use centrifugation to dewater it. Centrifugation is currently being used by a wide range of industrial concerns.

The performance of sludge dewatering by centrifugation depends on the feed rate, the rotational velocity of the drum, and the sludge composition and concentration. Assuming proper design and operation, the solids content of the sludge can be increased to 20-35 percent.

Advantages And Limitations. Sludge dewatering centrifuges have minimal space requirements and show a high degree of effluent clarification.   The operation is simple, clean, and relatively inexpensive. The area required for a centrifuge system installation is less than that required for a filter system or sludge drying bed of equal capacity, and the initial cost is lower.

Centrifuges have a high power cost that partially offsets the low initial cost. Special consideration must also be given to providing sturdy foundations and soundproofing because of the vibration and noise that result from centrifuge operation. Adequate electrical power must also be provided since large motors are required. The major difficulty encountered in the operation of centrifuges has been the disposal of the concentrate which is relatively high in suspended, non-settling solids.

Operational Factors. Reliability: Centrifugation is highly reliable with proper control of factors such as sludge feed, consistency, and temperature. Pretreatment such as grit removal and coagulant addition may be necessary, depending on the composition of the sludge and on the type of centrifuge employed.

Maintainability: Maintenance consists of periodic lubrication, cleaning, and inspection. The frequency and degree of inspection required varies depending on the type of sludge solids being dewatered and the maintenance service conditions. If the sludge is abrasive, it is recommended that the first inspection of the rotating assembly be made after approximately 1,000 hours of operation. If the sludge is not abrasive or corrosive, then the initial inspection might be delayed. Centrifuges not equipped with a continuous sludge discharge system require periodic shutdowns for manual sludge cake removal.

Solid Waste Aspects: Sludge dewatered in the centrifugation process may be disposed of by landfill. The clarified effluent (centrate), if high in dissolved or suspended solids, may require further treatment prior to discharge.

Demonstration Status. Centrifugation is currently used in a great many commercial applications to dewater sludge. Work is underway to improve the efficiency, increase the capacity, and lower the costs associated with centrifugation.

Coalescing

The basic principle of coalescence involves the preferential wetting of a coalescing medium by oil droplets which accumulate on the medium and then rise to the surface of the solution as they combine to form larger particles. The most important requirements for coalescing

media are wettability for oil and large surface area. Monofilament line is sometimes used as a coalescing medium.

Coalescing stages may be integrated with a wide variety of gravity oil separation devices, and some systems may incorporate several coalescing stages. In general a preliminary oil skimming step is desirable to avoid overloading the coalescer.

One commercially marketed system for oily waste treatment combines coalescing with inclined plate separation and filtration. In this system, the oily wastes flow into an inclined plate settler. This unit consists of a stack of inclined baffle plates in a cylindrical container with an oil collection chamber at the top. The oil droplets rise and impinge upon the undersides of the plates. They then migrate upward to a guide rib which directs the oil to the oil collection chamber, from which oil is discharged for reuse or disposal.

The oily water continues on through another cylinder containing replaceable filter cartridges, which remove suspended particles from the waste. From there the wastewater enters a final cylinder in which the coalescing material is housed. As the oily water passes through the many small, irregular, continuous passages in the coalescing material, the oil droplets coalesce and rise to an oil collection chamber.

Application and Performance. Coalescing is used to treat oily wastes which do not separate readily in simple gravity systems. The three stage system described above has achieved effluent concentrations of 10-15 mg/l oil and grease from raw waste concentrations of 1000 mg/l or more.

Advantages and Limitations. Coalescing allows removal of oil droplets too finely dispersed for conventional gravity separation-skimming technology. It also can significantly reduce the residence times (and therefore separator volumes) required to achieve separation of oil from some wastes. Because of its simplicity, coalescing provides generally high reliability and low capital and operating costs. Coalescing is not generally effective in removing soluble or chemically stabilized emulsified oils. To avoid plugging, coalescers must be protected by pretreatment from very high concentrations of free oil and grease and suspended solids. Frequent replacement of prefilters may be necessary when raw waste oil concentrations are high.

Operational Factors. Reliability: Coalescing is inherently highly reliable since there are no moving parts, and the coalescing substrate (monofilament, etc.) is inert in the process and therefore not subject to frequent regeneration or replacement requirements. Large loads or inadequate pretreatment, however, may result in plugging or bypass of coalescing stages.

Maintainability: Maintenance requirements are generally limited to replacement of the coalescing medium on an infrequent basis.

Solid Waste Aspects: No appreciable solid waste is generated by this process.

Demonstration Status. Coalescing has been fully demonstrated in industries generating oily wastewater, although none are currently not in use at any battery manufacturing facilities.

Cyanide Oxidation By Chlorine

Cyanide oxidation using chlorine is widely used in industrial waste treatment to oxidize cyanide. Chlorine can be utilized in either the elemental or hypochlorite forms. This classic procedure can be illustrated by the following two step chemical reaction:

1. $Cl_2 + NaCN + 2NaOH = NaCNO + 2NaCl + H_2O$

2. $3Cl_2 + 6NaOH + 2NaCNO = 2NaHCO_3 + N_2 + 6NaCl + 2H_2O$
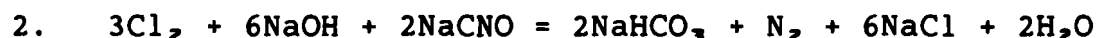
The reaction presented as equation (2) for the oxidation of cyanate is the final step in the oxidation of cyanide. A complete system for the alkaline chlorination of cyanide is shown in Figure VII-27.

The alkaline chlorination process oxidizes cyanides to carbon dioxide and nitrogen. The equipment often consists of an equalization tank followed by two reaction tanks, although the reaction can be carried out in a single tank. Each tank has an electronic recorder-controller to maintain required conditions with respect to pH and oxidation reduction potential (ORP). In the first reaction tank, conditions are adjusted to oxidize cyanides to cyanates. To effect the reaction, chlorine is metered to the reaction tank as required to maintain the ORP in the range of 350 to 400 millivolts, and 50 percent aqueous caustic soda is added to maintain a pH range of 9.5 to 10. In the second reaction tank, conditions are maintained to oxidize cyanate to carbon dioxide and nitrogen. The desirable ORP and pH for this reaction are 600 millivolts and a pH of 8.0. Each of the reaction tanks is equipped with a propeller agitator designed to provide approximately one turnover per minute. Treatment by the batch process is accomplished by using two tanks, one for collection of water over a specified time period, and one tank for the treatment of an accumulated batch. If dumps of concentrated wastes are frequent, another tank may be required to equalize the flow to the treatment tank. When the holding tank is full, the liquid is transferred to the reaction tank for treatment. After treatment, the supernatant is discharged and the sludges are collected for removal and ultimate disposal.

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Application and Performance. The oxidation of cyanide waste by chlorine is a classic process and is found in most industrial plants using cyanide. This process is capable of achieving effluent levels that are nondetectable. The process is potentially applicable to battery facilities where cyanide is a component in cell wash formulations.

Advantages and Limitations. Some advantages of chlorine oxidation for handling process effluents are operation at ambient temperature, suitability for automatic control, and low cost. Disadvantages include the need for careful pH control, possible chemical interference in the treatment of mixed wastes, and the potential hazard of storing and handling chlorine gas.

Operational Factors. Reliability: Chlorine oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge and recalibration of instruments.

Solid Waste Aspects: There is no solid waste problem associated with chlorine oxidation.

Demonstration Status. The oxidation of cyanide wastes by chlorine is a widely used process in plants using cyanide in cleaning and metal processing baths.

Cyanide Oxidation By Ozone

Ozone is a highly reactive oxidizing agent which is approximately ten times more soluble than oxygen on a weight basis in water. Ozone may be produced by several methods, but the silent electrical discharge method is predominant in the field. The silent electrical discharge process produces ozone by passing oxygen or air between electrodes separated by an insulating material. A complete ozonation system is represented in Figure VII-28.

Application and Performance. Ozonation has been applied commercially to oxidize cyanides, phenolic chemicals, and organo-metal complexes. Its applicability to photographic wastewaters has been studied in the laboratory with good results. Ozone is used in industrial waste treatment primarily to oxidize cyanide to cyanate and to oxidize phenols and dyes to a variety of colorless nontoxic products.

Oxidation of cyanide to cyanate is illustrated below:

$$CN^- + O_3 = CNO^- + O_2$$
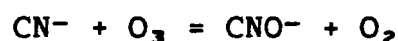
Continued exposure to ozone will convert the cyanate formed to carbon dioxide and ammonia; however, this is not economically practical.

Ozone oxidation of cyanide to cyanate requires 1.8 to 2.0 pounds ozone per pound of CN-; complete oxidation requires 4.6 to 5.0 pounds ozone per pound of CN-. Zinc, copper, and nickel cyanides are easily destroyed to a nondetectable level, but cobalt and iron cyanides are more resistant to ozone treatment.

Advantages and Limitations. Some advantages of ozone oxidation for handling process effluents are its suitability to automatic control and on-site generation and the fact that reaction products are not chlorinated organics and no dissolved solids are added in the treatment step. Ozone in the presence of activated carbon, ultraviolet, and other promoters shows promise of reducing reaction time and improving ozone utilization, but the process at present is limited by high capital expense, possible chemical interference in the treatment of mixed wastes, and an energy requirement of 25 kwh/kg of ozone generated. Cyanide is not economically oxidized beyond the cyanate form.

Operational Factors. Reliability: Ozone oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge, and periodic renewal of filters and desiccators required for the input of clean dry air; filter life is a function of input concentrations of detrimental constituents.

Solid Waste Aspects: Pretreatment to eliminate substances which will interfere with the process may be necessary. Dewatering of sludge generated in the ozone oxidation process or in an "in line" process may be desirable prior to disposal.

Cyanide Oxidation By Ozone With UV Radiation

One of the modifications of the ozonation process is the simultaneous application of ultraviolet light and ozone for the treatment of wastewater, including treatment of halogenated organics. The combined action of these two forms produces reactions by photolysis, photosensitization, hydroxylation, oxygenation and oxidation. The process is unique because several reactions and reaction species are active simultaneously.

Ozonation is facilitated by ultraviolet absorption because both the ozone and the reactant molecules are raised to a higher energy state so that they react more rapidly. In addition, free radicals for use in the reaction are readily hydrolyzed by the water present. The

energy and reaction intermediates created by the introduction of both ultraviolet and ozone greatly reduce the amount of ozone required compared with a system using ozone alone. Figure VII-29 shows a three-stage UV-ozone system. A system to treat mixed cyanides requires pretreatment that involves chemical coagulation, sedimentation, clarification, equalization, and pH adjustment.

Application and Performance. The ozone-UV radiation process was developed primarily for cyanide treatment in the electroplating and color photo-processing areas. It has been successfully applied to mixed cyanides and organics from organic chemicals manufacturing processes. The process is particularly useful for treatment of complexed cyanides such as ferricyanide, copper cyanide and nickel cyanide, which are resistant to ozone alone.

Ozone combined with UV radiation is a relatively new technology. Four units are currently in operation and all four treat cyanide bearing waste.

Ozone-UV treatment could be used in battery plants to destroy cyanide present in waste streams from some cell wash operations.

Cyanide Oxidation By Hydrogen Peroxide

Hydrogen peroxide oxidation removes both cyanide and metals in cyanide containing wastewaters. In this process, cyanide bearing waters are heated to 49 - 54°C (120 - 130°F) and the pH is adjusted to 10.5 - 11.8. Formalin (37 percent formaldehyde) is added while the tank is vigorously agitated. After 2-5 minutes, a proprietary peroxygen compound (41 percent hydrogen peroxide with a catalyst and additives) is added. After an hour of mixing, the reaction is complete. The cyanide is converted to cyanate and the metals are precipitated as oxides or hydroxides. The metals are then removed from solution by either settling or filtration.

The main equipment required for this process is two holding tanks equipped with heaters and air spargers or mechanical stirrers. These tanks may be used in a batch or continuous fashion, with one tank being used for treatment while the other is being filled. A settling tank or a filter is needed to concentrate the precipitate.

Application and Performance. The hydrogen peroxide oxidation process is applicable to cyanidebearing wastewaters, especially those containing metal-cyanide complexes. In terms of waste reduction performance, this process can reduce total cyanide to less than 0.1 mg/l and the zinc or cadmium to less than 1.0 mg/l.

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Advantages and Limitations. Chemical costs are similar to those for alkaline chlorination using chlorine and lower than those for treatment with hypochlorite. All free cyanide reacts and is completely oxidized to the less toxic cyanate state. In addition, the metals precipitate and settle quickly, and they may be recoverable in many instances. However, the process requires energy expenditures to heat the wastewater prior to treatment.

Demonstration Status. This treatment process was introduced in 1971 and is used in several facilities. No battery manufacturing plants use oxidation by hydrogen peroxide.

Evaporation

Evaporation is a concentration process. Water is evaporated from a solution, increasing the concentration of solute in the remaining solution. If the resulting water vapor is condensed back to liquid water, the evaporation-condensation process is called distillation. However, to be consistent with industry terminology, evaporation is used in this report to describe both processes. Both atmospheric and vacuum evaporation are commonly used in industry today. Specific evaporation techniques are shown in Figure VII-20 and discussed below.

Atmospheric evaporation could be accomplished simply by boiling the liquid. However, to aid evaporation, heated liquid is sprayed on an evaporation surface, and air is blown over the surface and subsequently released to the atmosphere. Thus, evaporation occurs by humidification of the air stream, similar to a drying process. Equipment for carrying out atmospheric evaporation is quite similar for most applications. The major element is generally a packed column with an accumulator bottom. Accumulated wastewater is pumped from the base of the column, through a heat exchanger, and back into the top of the column, where it is sprayed into the packing. At the same time, air drawn upward through the packing by a fan is heated as it contacts the hot liquid. The liquid partially vaporizes and humidifies the air stream. The fan then blows the hot, humid air to the outside atmosphere. A scrubber is often unnecessary because the packed column itself acts as a scrubber.

Another form of atmospheric evaporator also works on the air humidification principle, but the evaporated water is recovered for reuse by condensation. These air humidification techniques operate well below the boiling point of water and can utilize waste process heat to supply the energy required.

In vacuum evaporation, the evaporation pressure is lowered to cause the liquid to boil at reduced temperature. All of the water vapor is condensed and, to maintain the vacuum condition, noncondensible gases (air in particular) are removed by a vacuum pump. Vacuum evaporation

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may be either single or double effect. In double effect evaporation, two evaporators are used, and the water vapor from the first evaporator (which may be heated by steam) is used to supply heat to the second evaporator. As it supplies heat, the water vapor from the first evaporator condenses. Approximately equal quantities of wastewater are evaporated in each unit; thus, the double effect system evaporates twice the amount of water that a single effect system does, at nearly the same cost in energy but with added capital cost and complexity. The double effect technique is thermodynamically possible because the second evaporator is maintained at lower pressure (higher vacuum) and, therefore, lower evaporation temperature. Another means of increasing energy efficiency is vapor recompression (thermal or mechanical), which enables heat to be transferred from the condensing water vapor to the evaporating wastewater. Vacuum evaporation equipment may be classified as submerged tube or climbing film evaporation units.

In the most commonly used submerged tube evaporator, the heating and condensing coil are contained in a single vessel to reduce capital cost. The vacuum in the vessel is maintained by an eductor-type pump, which creates the required vacuum by the flow of the condenser cooling water through a venturi. Waste water accumulates in the bottom of the vessel, and it is evaporated by means of submerged steam coils. The resulting water vapor condenses as it contacts the condensing coils in the top of the vessel. The condensate then drips off the condensing coils into a collection trough that carries it out of the vessel. Concentrate is removed from the bottom of the vessel.

The major elements of the climbing film evaporator are the evaporator, separator, condenser, and vacuum pump. Waste water is "drawn" into the system by the vacuum so that a constant liquid level is maintained in the separator. Liquid enters the steam-jacketed evaporator tubes, and part of it evaporates so that a mixture of vapor and liquid enters the separator. The design of the separator is such that the liquid is continuously circulated from the separator to the evaporator. The vapor entering the separator flows out through a mesh entrainment separator to the condenser, where it is condensed as it flows down through the condenser tubes. The condensate, along with any entrained air, is pumped out of the bottom of the condenser by a liquid ring vacuum pump. The liquid seal provided by the condensate keeps the vacuum in the system from being broken.

Application and Performance. Both atmospheric and vacuum evaporation are used in many industrial plants, mainly for the concentration and recovery of process solutions. Many of these evaporators also recover water for rinsing. Evaporation has also been applied to recovery of phosphate metal cleaning solutions.

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In theory, evaporation should yield a concentrate and a deionized condensate. Actually, carry-over has resulted in condensate metal concentrations as high as 10 mg/l, although the usual level is less than 3 mg/l, pure enough for most final rinses. The condensate may also contain organic brighteners and antifoaming agents. These can be removed with an activated carbon bed, if necessary. Samples from one plant showed 1,900 mg/l zinc in the feed, 4,570 mg/l in the concentrate, and 0.4 mg/l in the condensate. Another plant had 416 mg/l copper in the feed and 21,800 mg/l in the concentrate. Chromium analysis for that plant indicated 5,060 mg/l in the feed and 27,500 mg/l in the concentrate. Evaporators are available in a range of capacities, typically from 15 to 75 gph, and may be used in parallel arrangements for processing of higher flow rates.

Advantages and Limitations. Advantages of the evaporation process are that it permits recovery of a wide variety of process chemicals, and it is often applicable to concentration or removal of compounds which cannot be accomplished by any other means. The major disadvantage is that the evaporation process consumes relatively large amounts of energy for the evaporation of water. However, the recovery of waste heat from many industrial processes (e.g., diesel generators, incinerators, boilers and furnaces) should be considered as a source of this heat for a totally integrated evaporation system. Also, in some cases solar heating could be inexpensively and effectively applied to evaporation units. For some applications, pretreatment may be required to remove solids or bacteria which tend to cause fouling in the condenser or evaporator. The buildup of scale on the evaporator surfaces reduces the heat transfer efficiency and may present a maintenance problem or increase operating cost. However, it has been demonstrated that fouling of the heat transfer surfaces can be avoided or minimized for certain dissolved solids by maintaining a seed slurry which provides preferential sites for precipitate deposition. In addition, low temperature differences in the evaporator will eliminate nucleate boiling and supersaturation effects. Steam distillable impurities in the process stream are carried over with the product water and must be handled by pre or post treatment.

Operational Factors. Reliability: Proper maintenance will ensure a high degree of reliability for the system. Without such attention, rapid fouling or deterioration of vacuum seals may occur, especially when handling corrosive liquids.

Maintainability: Operating parameters can be automatically controlled. Pretreatment may be required, as well as periodic cleaning of the system. Regular replacement of seals, especially in a corrosive environment, may be necessary.

Solid Waste Aspects: With only a few exceptions, the process does not generate appreciable quantities of solid waste.

Demonstration Status. Evaporation is a fully developed, commercially available wastewater treatment system. It is used extensively to recover plating chemicals in the electroplating industry and a pilot scale unit has been used in connection with phosphating of aluminum. Proven performance in silver recovery indicates that evaporation could be a useful treatment operation for the photographic industry, as well as for metal finishing. One battery plant has recently reported showing the use of evaporation.

Flotation

Flotation is the process of causing particles such as metal hydroxides or oil to float to the surface of a tank where they can be concentrated and removed. This is accomplished by releasing gas bubbles which attach to the solid particles, increasing their buoyancy and causing them to float. In principle, this process is the opposite of sedimentation. Figure VII-24 shows one type of flotation system.

Flotation is used primarily in the treatment of wastewater streams that carry heavy loads of finely divided suspended solids or oil. Solids having a specific gravity only slightly greater than 1.0, which would require abnormally long sedimentation times, may be removed in much less time by flotation.

This process may be performed in several ways: foam, dispersed air, dissolved air, gravity, and vacuum flotation are the most commonly used techniques. Chemical additives are often used to enhance the performance of the flotation process.

The principal difference among types of flotation is the method of generating the minute gas bubbles (usually air) in a suspension of water and small particles. Chemicals may be used to improve the efficiency with any of the basic methods. The following paragraphs describe the different flotation techniques and the method of bubble generation for each process.

Froth Flotation – Froth flotation is based on differences in the physiochemical properties in various particles. Wettability and surface properties affect the particles' ability to attach themselves to gas bubbles in an aqueous medium. In froth flotation, air is blown through the solution containing flotation reagents. The particles with water repellant surfaces stick to air bubbles as they rise and are brought to the surface. A mineralized froth layer, with mineral particles attached to air bubbles, is formed. Particles of other minerals which are readily wetted by water do not stick to air bubbles and remain in suspension.

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Dispersed Air Flotation - In dispersed air flotation, gas bubbles are generated by introducing the air by means of mechanical agitation with impellers or by forcing air through porous media. Dispersed air flotation is used mainly in the metallurgical industry.

Dissolved Air Flotation - In dissolved air flotation, bubbles are produced by releasing air from a supersaturated solution under relatively high pressure. There are two types of contact between the gas bubbles and particles. The first type is predominant in the flotation of flocculated materials and involves the entrapment of rising gas bubbles in the flocculated particles as they increase in size. The bond between the bubble and particle is one of physical capture only. The second type of contact is one of adhesion. Adhesion results from the intermolecular attraction exerted at the interface between the solid particle and gaseous bubble.

Vacuum Flotation - This process consists of saturating the waste water with air either directly in an aeration tank, or by permitting air to enter on the suction of a wastewater pump. A partial vacuum is applied, which causes the dissolved air to come out of solution as minute bubbles. The bubbles attach to solid particles and rise to the surface to form a scum blanket, which is normally removed by a skimming mechanism. Grit and other heavy solids that settle to the bottom are generally raked to a central sludge pump for removal. A typical vacuum flotation unit consists of a covered cylindrical tank in which a partial vacuum is maintained. The tank is equipped with scum and sludge removal mechanisms. The floating material is continuously swept to the tank periphery, automatically discharged into a scum trough, and removed from the unit by a pump also under partial vacuum. Auxilliary equipment includes an aeration tank for saturating the wastewater with air, a tank with a short retention time for removal of large bubbles, vacuum pumps, and sludge pumps.

Application and Performance. The primary variables for flotation design are pressure, feed solids concentration, and retention period. The suspended solids in the effluent decrease, and the concentration of solids in the float increases with increasing retention period. When the flotation process is used primarily for clarification, a retention period of 20 to 30 minutes is adequate for separation and concentration.

Advantages and Limitations. Some advantages of the flotation process are the high levels of solids separation achieved in many applications, the relatively low energy requirements, and the adaptability to meet the treatment requirements of different waste types. Limitations of flotation are that it often requires addition of chemicals to enhance process performance and that it generates large quantities of solid waste.

Operational Factors. Reliability: Flotation systems normally are very reliable with proper maintenance of the sludge collector mechanism and the motors and pumps used for aeration.

Maintainability: Routine maintenance is required on the pumps and motors. The sludge collector mechanism is subject to possible corrosion or breakage and may require periodic replacement.

Solid Waste Aspects: Chemicals are commonly used to aid the flotation process by creating a surface or a structure that can easily adsorb or entrap air bubbles. Inorganic chemicals, such as the aluminum and ferric salts, and activated silica, can bind the particulate matter together and create a structure that can entrap air bubbles. Various organic chemicals can change the nature of either the air-liquid interface or the solid-liquid interface, or both. These compounds usually collect on the interface to bring about the desired changes. The added chemicals plus the particles in solution combine to form a large volume of sludge which must be further treated or properly disposed.

Demonstration Status. Flotation is a fully developed process and is readily available for the treatment of a wide variety of industrial waste streams. Flotation separation has been used in two battery manufacturing plants as a part of precipitation systems for metals removal.

Gravity Sludge Thickening

In the gravity thickening process, dilute sludge is fed from a primary settling tank or clarifier to a thickening tank where rakes stir the sludge gently to densify it and to push it to a central collection well. The supernatant is returned to the primary settling tank. The thickened sludge that collects on the bottom of the tank is pumped to dewatering equipment or hauled away. Figure VII-18 shows the construction of a gravity thickener.

Application and Performance. Thickeners are generally used in facilities where the sludge is to be further dewatered by a compact mechanical device such as a vacuum filter or centrifuge. Doubling the solids content in the thickener substantially reduces capital and operating cost of the subsequent dewatering device and also reduces cost for hauling. The process is potentially applicable to almost any industrial plant.

Organic sludges from sedimentation units of one to two percent solids concentration can usually be gravity thickened to six to ten percent; chemical sludges can be thickened to four to six percent.

Advantages and Limitations. The principal advantage of a gravity sludge thickening process is that it facilitates further sludge dewatering. Other advantages are high reliability and minimum maintenance requirements.

Limitations of the sludge thickening process are its sensitivity to the flow rate through the thickener and the sludge removal rate. These rates must be low enough not to disturb the thickened sludge.

Operational Factors. Reliability: Reliability is high with proper design and operation. A gravity thickener is designed on the basis of square feet per pound of solids per day, in which the required surface area is related to the solids entering and leaving the unit. Thickener area requirements are also expressed in terms of mass loading, grams of solids per square meter per day (lbs/sq ft/day).

Maintainability: Twice a year, a thickener must be shut down for lubrication of the drive mechanisms. Occasionally, water must be pumped back through the system in order to clear sludge pipes.

Solid Waste Aspects: Thickened sludge from a gravity thickening process will usually require further dewatering prior to disposal, incineration, or drying. The clear effluent may be recirculated in part, or it may be subjected to further treatment prior to discharge.

Demonstration Status. Gravity sludge thickeners are used throughout industry to reduce water content to a level where the sludge may be efficiently handled. Further dewatering is usually practiced to minimize costs of hauling the sludge to approved landfill areas. Sludge thickening is used in seven battery manufacturing plants.

Insoluble Starch Xanthate

Insoluble starch xanthate is essentially an ion exchange medium used to remove dissolved heavy metals from wastewater. The water may then either be reused (recovery application) or discharged (end-of-pipe application). In a commercial electroplating operation, starch xanthate is coated on a filter medium. Rinse water containing dragged out heavy metals is circulated through the filters and then reused for rinsing. The starch-heavy metal complex is disposed of and replaced periodically. Laboratory tests indicate that recovery of metals from the complex is feasible, with regeneration of the starch xanthate. Besides electroplating, starch xanthate is potentially applicable to any other industrial plants where dilute metal wastewater streams are generated. Its present use is limited to one electroplating plant.

Ion Exchange

Ion exchange is a process in which ions, held by electrostatic forces to charged functional groups on the surface of the ion exchange resin, are exchanged for ions of similar charge from the solution in which the resin is immersed. This is classified as a sorption process because the exchange occurs on the surface of the resin, and the exchanging ion must undergo a phase transfer from solution phase to solid phase. Thus, ionic contaminants in a waste stream can be exchanged for the harmless ions of the resin.

Although the precise technique may vary slightly according to the application involved, a generalized process description follows. The wastewater stream being treated passes through a filter to remove any solids, then flows through a cation exchanger which contains the ion exchange resin. Here, metallic impurities such as copper, iron, and trivalent chromium are retained. The stream then passes through the anion exchanger and its associated resin. Hexavalent chromium, for example, is retained in this stage. If one pass does not reduce the contaminant levels sufficiently, the stream may then enter another series of exchangers. Many ion exchange systems are equipped with more than one set of exchangers for this reason.

The other major portion of the ion exchange process concerns the regeneration of the resin, which now holds those impurities retained from the waste stream. An ion exchange unit with in-place regeneration is shown in Figure VII-21 (Page 591). Metal ions such as nickel are removed by an acid, cation exchange resin, which is regenerated with hydrochloric or sulfuric acid, replacing the metal ion with one or more hydrogen ions. Anions such as dichromate are removed by a basic, anion exchange resin, which is regenerated with sodium hydroxide, replacing the anion with one or more hydroxyl ions. The three principal methods employed by industry for regenerating the spent resin are:

A) Replacement Service: A regeneration service replaces the spent resin with regenerated resin, and regenerates the spent resin at its own facility. The service then has the problem of treating and disposing of the spent regenerant.

B) In-Place Regeneration: Some establishments may find it less expensive to do their own regeneration. The spent resin column is shut down for perhaps an hour, and the spent resin is regenerated. This results in one or more waste streams which must be treated in an appropriate manner. Regeneration is performed as the resins require it, usually every few months.

C) Cyclic Regeneration: In this process, the regeneration of the spent resins takes place within the ion exchange unit itself in

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alternating cycles with the ion removal process. A regeneration
frequency of twice an hour is typical. This very short cycle time
permits operation with a very small quantity of resin and with
fairly concentrated solutions, resulting in a very compact system.
Again, this process varies according to application, but the
regeneration cycle generally begins with caustic being pumped
through the anion exchanger, carrying out hexavalent chromium, for
example, as sodium dichromate. The sodium dichromate stream then
passes through a cation exchanger, converting the sodium
dichromate to chromic acid. After concentration by evaporation or
other means, the chromic acid can be returned to the process line.
Meanwhile, the cation exchanger is regenerated with sulfuric acid,
resulting in a waste acid stream containing the metallic
impurities removed earlier. Flushing the exchangers with water
completes the cycle. Thus, the wastewater is purified and, in
this example, chromic acid is recovered. The ion exchangers, with
newly regenerated resin, then enter the ion removal cycle again.

Application and Performance. The list of pollutants for which the ion
exchange system has proven effective includes aluminum, arsenic,
cadmium, chromium (hexavalent and trivalent), copper, cyanide, gold,
iron, lead, manganese, nickel, selenium, silver, tin, zinc, and more.
Thus, it can be applied to a wide variety of industrial concerns.
Because of the heavy concentrations of metals in their wastewater, the
metal finishing industries utilize ion exchange in several ways. As
an end-of-pipe treatment, ion exchange is certainly feasible, but its
greatest value is in recovery applications. It is commonly used as an
integrated treatment to recover rinse water and process chemicals.
Some electroplating facilities use ion exchange to concentrate and
purify plating baths. Also, many industrial concerns, including a
number of battery manufacturing plants, use ion exchange to reduce
salt concentrations in incoming water sources.

Ion exchange is highly efficient at recovering metal bearing solu-
tions. Recovery of chromium, nickel, phosphate solution, and sulfuric
acid from anodizing is commercial. A chromic acid recovery efficiency
of 99.5 percent has been demonstrated. Typical data for purification
of rinse water have been reported. Sampling at one battery
manufacturing plant characterized influent and effluent streams for an
ion exchange unit on a silver bearing waste. This system was in
start-up at the time of sampling, however, and was not found to be
operating effectively.

Table VII-20

Ion Exchange Performance

Parameter	Plant A		Plant B	
	Prior To Purification	After Purification	Prior To Purification	After Purification
All Values mg/l				
Al	5.6	0.20	-	-
Cd	5.7	0.00	-	-
Cr+3	3.1	0.01	-	-
Cr+6	7.1	0.01	-	-
Cu	4.5	0.09	43.0	0.10
CN	9.8	0.04	3.40	0.09
Au	-	-	2.30	0.10
Fe	7.4	0.01	-	-
Pb	-	-	1.70	0.01
Mn	4.4	0.00	-	-
Ni	6.2	0.00	1.60	0.01
Ag	1.5	0.00	9.10	0.01
SO4	-	-	210.00	2.00
Sn	1.7	0.00	1.10	0.10
Zn	14.8	0.40	-	-

Advantages and Limitations. Ion exchange is a versatile technology applicable to a great many situations. This flexibility, along with its compact nature and performance, makes ion exchange a very effective method of waste water treatment. However, the resins in these systems can prove to be a limiting factor. The thermal limits of the anion resins, generally in the vicinity of 60°C, could prevent its use in certain situations. Similarly, nitric acid, chromic acid, and hydrogen peroxide can all damage the resins, as will iron, manganese, and copper when present with sufficient concentrations of dissolved oxygen. Removal of a particular trace contaminant may be uneconomical because of the presence of other ionic species that are preferentially removed. The regeneration of the resins presents its own problems. The cost of the regenerative chemicals can be high. In addition, the waste streams originating from the regeneration process are extremely high in pollutant concentrations, although low in volume. These must be further processed for proper disposal.

Operational Factors. Reliability: With the exception of occasional clogging or fouling of the resins, ion exchange has proved to be a highly dependable technology.

Maintainability: Only the normal maintenance of pumps, valves, piping and other hardware used in the regeneration process is required.

Solid Waste Aspects: Few, if any, solids accumulate within the ion exchangers, and those which do appear are removed by the regeneration process. Proper prior treatment and planning can eliminate solid buildup problems altogether. The brine resulting from regeneration of the ion exchange resin most usually must be treated to remove metals before discharge. This can generate solid waste.

Demonstration Status. All of the applications mentioned in this document are available for commercial use, and industry sources estimate the number of units currently in the field at well over 120. The research and development in ion exchange is focusing on improving the quality and efficiency of the resins, rather than new applications. Work is also being done on a continuous regeneration process whereby the resins are contained on a fluid-transfusible belt. The belt passes through a compartmented tank with ion exchange, washing, and regeneration sections. The resins are therefore continually used and regenerated. No such system, however, has been reported beyond the pilot stage.

Ion exchange is used for nickel recovery at one battery plant, for silver and water recovery at another, and for trace nickel and cadmium removal at a third.

Membrane Filtration

Membrane filtration is a treatment system for removing precipitated metals from a wastewater stream. It must therefore be preceded by those treatment techniques which will properly prepare the wastewater for solids removal. Typically, a membrane filtration unit is preceded by pH adjustment or sulfide addition for precipitation of the metals. These steps are followed by the addition of a proprietary chemical reagent which causes the precipitate to be non-gelatinous, easily dewatered, and highly stable. The resulting mixture of pretreated wastewater and reagent is continuously recirculated through a filter module and back into a recirculation tank. The filter module contains tubular membranes. While the reagent-metal hydroxide precipitate mixture flows through the inside of the tubes, the water and any dissolved salts permeate the membrane. When the recirculating slurry reaches a concentration of 10 to 15 percent solids, it is pumped out of the system as sludge.

Application and Performance. Membrane filtration appears to be applicable to any wastewater or process water containing metal ions which can be precipitated using hydroxide, sulfide or carbonate precipitation. It could function as the primary treatment system, but also might find application as a polishing treatment (after precipitation and settling) to ensure continued compliance with metals limitations. Membrane filtration systems are being used in a number of industrial applications, particularly in the metal finishing area.

They have also been used for heavy metals removal in the metal fabrication industry and the paper industry.

The permeate is claimed by one manufacturer to contain less than the effluent concentrations shown in the following table, regardless of the influent concentrations. These claims have been largely substantiated by the analysis of water samples at various plants in various industries.

In the performance predictions for this technology, pollutant concentrations are reduced to the levels shown below unless lower levels are present in the influent stream.

Table VII-21

MEMBRANE FILTRATION SYSTEM EFFLUENT

Specific Metal	Manufacturers Guarantee	Plant 19066 In	Out	Plant 31022 In	Out	Predicted Performance
Al	0.5	---	---	---	---	
Cr, (+6)	0.02	0.46	0.01	5.25	<0.005	
Cr (T)	0.03	4.13	0.018	98.4	0.057	0.05
Cu	0.1	18.8	0.043	8.00	0.222	0.20
Fe	0.1	288	0.3	21.1	0.263	0.30
Pb	0.05	0.652	0.01	0.288	0.01	0.05
CN	0.02	<0.005	<0.005	<0.005	<0.005	0.02
Ni	0.1	9.56	0.017	194	0.352	0.40
Zn	0.1	2.09	0.046	5.00	0.051	0.10
TSS	---	632	0.1	13.0	8.0	10.0

Advantages and Limitations. A major advantage of the membrane filtration system is that installations can use most of the conventional end-of-pipe systems that may already be in place. Removal efficiencies are claimed to be excellent, even with sudden variation of pollutant input rates; however, the effectiveness of the membrane filtration system can be limited by clogging of the filters. Because pH changes in the waste stream greatly intensify clogging problems, the pH must be carefully monitored and controlled. Clogging can force the shutdown of the system and may interfere with production. In addition, relatively high capital cost of this system may limit its use.

Operational Factors. Reliability: Membrane filtration has been shown to be a very reliable system, provided that the pH is strictly controlled. Improper pH can result in the clogging of the membrane. Also, surges in the flow rate of the waste stream must be controlled

in order to prevent solids from passing through the filter and into the effluent.

Maintainability: The membrane filters must be regularly monitored, and cleaned or replaced as necessary. Depending on the composition of the waste stream and its flow rate, frequent cleaning of the filters may be required. Flushing with hydrochloric acid for 6-24 hours will usually suffice. In addition, the routine maintenance of pumps, valves, and other plumbing is required.

Solid Waste Aspects: When the recirculating reagent-precipitate slurry reaches 10 to 15 percent solids, it is pumped out of the system. It can then be disposed of directly or it can undergo a dewatering process. Because this sludge contains toxic metals, it requires proper disposal.

Demonstration Status. There are more than 25 membrane filtration systems presently in use on metal finishing and similar wastewaters. Bench scale and pilot studies are being run in an attempt to expand the list of pollutants for which this system is known to be effective. Although there are no data on the use of membrane filtration in battery manufacturing plants, the concept has been successfully demonstrated using battery plant wastewater. A unit has been installed at one battery manufacturing plant based on these tests.

Peat Adsorption

Peat moss is a complex natural organic material containing lignin and cellulose as major constituents. These constituents, particularly lignin, bear polar functional groups, such as alcohols, aldehydes, ketones, acids, phenolic hydroxides, and ethers, that can be involved in chemical bonding. Because of the polar nature of the material, its adsorption of dissolved solids such as transition metals and polar organic molecules is quite high. These properties have led to the use of peat as an agent for the purification of industrial wastewater.

Peat adsorption is a "polishing" process which can achieve very low effluent concentrations for several pollutants. If the concentrations of pollutants are above 10 mg/l, then peat adsorption must be preceded by pH adjustment for metals precipitation and subsequent clarification. Pretreatment is also required for chromium wastes using ferric chloride and sodium sulfide. The wastewater is then pumped into a large metal chamber called a kier which contains a layer of peat through which the waste stream passes. The water flows to a second kier for further adsorption. The wastewater is then ready for discharge. This system may be automated or manually operated.

Application and Performance. Peat adsorption can be used in battery manufacturing for removal of residual dissolved metals from clarifier effluent. Peat moss may be used to treat wastewaters containing heavy metals such as mercury, cadmium, zinc, copper, iron, nickel, chromium, and lead, as well as organic matter such as oil, detergents, and dyes. Peat adsorption is currently used commercially at a textile plant, a newsprint facility, and a metal reclamation operation.

The following table contains performance figures obtained from pilot plant studies. Peat adsorption was preceded by pH adjustment for precipitation and by clarification.

Table VII-22

PEAT ADSOPRTION PERFORMANCE

Pollutant (mg/l)	In	Out
Cr+6	35,000	0.04
Cu	250	0.24
CN	36.0	0.7
Pb	20.0	0.025
Hg	1.0	0.02
Ni	2.5	0.07
Ag	1.0	0.05
Sb	2.5	0.9
Zn	1.5	0.25

In addition, pilot plant studies have shown that chelated metal wastes, as well as the chelating agents themselves, are removed by contact with peat moss.

Advantages and Limitations. The major advantages of the system include its ability to yield low pollutant concentrations, its broad scope in terms of the pollutants eliminated, and its capacity to accept wide variations of waste water composition.

Limitations include the cost of purchasing, storing, and disposing of the peat moss; the necessity for regular replacement of the peat may lead to high operation and maintenance costs. Also, the pH adjustment must be altered according to the composition of the waste stream.

Operational Factors. Reliability: The question of long term reliability is not yet fully answered. Although the manufacturer reports it to be a highly reliable system, operating experience is needed to verify the claim.

Maintainability: The peat moss used in this process soon exhausts its capacity to adsorb pollutants. At that time, the kiers must be opened, the peat removed, and fresh peat placed inside. Although this procedure is easily and quickly accomplished, it must be done at regular intervals, or the system's efficiency drops drastically.

Solid Waste Aspects: After removal from the kier, the spent peat must be eliminated. If incineration is used, precautions should be taken to insure that those pollutants removed from the water are not released again in the combustion process. Presence of sulfides in the spent peat, for example, will give rise to sulfur dioxide in the fumes from burning. The presence of significant quantities of toxic heavy metals in battery manufacturing wastewater will in general preclude incineration of peat used in treating these wastes.

Demonstration Status. Only three facilities currently use commercial adsorption systems in the United States - a textile manufacturer, a newsprint facility, and a metal reclamation firm. No data have been reported showing the use of peat adsorption in battery manufacturing plants.

Reverse Osmosis

The process of osmosis involves the passage of a liquid through a semipermeable membrane from a dilute to a more concentrated solution. Reverse osmosis (RO) is an operation in which pressure is applied to the more concentrated solution, forcing the permeate to diffuse through the membrane and into the more dilute solution. This filtering action produces a concentrate and a permeate on opposite sides of the membrane. The concentrate can then be further treated or returned to the original operation for continued use, while the permeate water can be recycled for use as clean water. Figure VII-22 depicts a reverse osmosis system.

As illustrated in Figure VII-23, there are three basic configurations used in commercially available RO modules: tubular, spiral-wound, and hollow fiber. All of these operate on the principle described above, the major difference being their mechanical and structural design characteristics.

The tubular membrane module uses a porous tube with a cellulose acetate membrane-lining. A common tubular module consists of a length of 2.5 cm (1 inch) diameter tube wound on a supporting spool and encased in a plastic shroud. Feed water is driven into the tube under pressures varying from 40 - 55 atm (600-800 psi). The permeate passes through the walls of the tube and is collected in a manifold while the concentrate is drained off at the end of the tube. A less widely used tubular RO module uses a straight tube contained in a housing, under the same operating conditions.

Spiral-wound membranes consist of a porous backing sandwiched between two cellulose acetate membrane sheets and bonded along three edges. The fourth edge of the composite sheet is attached to a large permeate collector tube. A spacer screen is then placed on top of the membrane sandwich and the entire stack is rolled around the centrally located tubular permeate collector. The rolled up package is inserted into a pipe able to withstand the high operating pressures employed in this process, up to 55 atm (800 psi) with the spiral-wound module. When the system is operating, the pressurized product water permeates the membrane and flows through the backing material to the central collector tube. The concentrate is drained off at the end of the container pipe and can be reprocessed or sent to further treatment facilities.

The hollow fiber membrane configuration is made up of a bundle of polyamide fibers of approximately 0.0075 cm (0.003 in.) OD and 0.0043 cm (0.0017 in.) ID. A commonly used hollow fiber module contains several hundred thousand of the fibers placed in a long tube, wrapped around a flow screen, and rolled into a spiral. The fibers are bent in a U-shape and their ends are supported by an epoxy bond. The hollow fiber unit is operated under 27 atm (400 psi), the feed water being dispersed from the center of the module through a porous distributor tube. Permeate flows through the membrane to the hollow interiors of the fibers and is collected at the ends of the fibers.

The hollow fiber and spiral-wound modules have a distinct advantage over the tubular system in that they are able to load a very large membrane surface area into a relatively small volume. However, these two membrane types are much more susceptible to fouling than the tubular system, which has a larger flow channel. This characteristic also makes the tubular membrane much easier to clean and regenerate than either the spiral-wound or hollow fiber modules. One manufacturer claims that their helical tubular module can be physically wiped clean by passing a soft porous polyurethane plug under pressure through the module.

Application and Performance. In a number of metal processing plants, the overflow from the first rinse in a countercurrent setup is directed to a reverse osmosis unit, where it is separated into two streams. The concentrated stream contains dragged out chemicals and is returned to the bath to replace the loss of solution due to evaporation and dragout. The dilute stream (the permeate) is routed to the last rinse tank to provide water for the rinsing operation. The rinse flows from the last tank to the first tank and the cycle is complete.

The closed-loop system described above may be supplemented by the addition of a vacuum evaporator after the RO unit in order to further reduce the volume of reverse osmosis concentrate. The evaporated

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vapor can be condensed and returned to the last rinse tank or sent on for further treatment.

The largest application has been for the recovery of nickel solutions. It has been shown that RO can generally be applied to most acid metal baths with a high degree of performance, providing that the membrane unit is not overtaxed. The limitations most critical here are the allowable pH range and maximum operating pressure for each particular configuration. Adequate prefiltration is also essential. Only three membrane types are readily available in commercial RO units, and their overwhelming use has been for the recovery of various acid metal baths. For the purpose of calculating performance predictions of this technology, a rejection ratio of 98 percent is assumed for dissolved salts, with 95 percent permeate recovery.

Advantages and Limitations. The major advantage of reverse osmosis for handling process effluents is its ability to concentrate dilute solutions for recovery of salts and chemicals with low power requirements. No latent heat of vaporization or fusion is required for effecting separations; the main energy requirement is for a high pressure pump. It requires relatively little floor space for compact, high capacity units, and it exhibits good recovery and rejection rates for a number of typical process solutions. A limitation of the reverse osmosis process for treatment of process effluents is its limited temperature range for satisfactory operation. For cellulose acetate systems, the preferred limits are 18° to 30°C (65° to 85°F); higher temperatures will increase the rate of membrane hydrolysis and reduce system life, while lower temperatures will result in decreased fluxes with no damage to the membrane. Another limitation is inability to handle certain solutions. Strong oxidizing agents, strongly acidic or basic solutions, solvents, and other organic compounds can cause dissolution of the membrane. Poor rejection of some compounds such as borates and low molecular weight organics is another problem. Fouling of membranes by slightly soluble components in solution or colloids has caused failures, and fouling of membranes by feed waters with high levels of suspended solids can be a problem. A final limitation is inability to treat or achieve high concentration with some solutions. Some concentrated solutions may have initial osmotic pressures which are so high that they either exceed available operating pressures or are uneconomical to treat.

Operational Factors. Reliability: Very good reliability is achieved so long as the proper precautions are taken to minimize the chances of fouling or degrading the membrane. Sufficient testing of the waste stream prior to application of an RO system will provide the information needed to insure a successful application.

Maintainability: Membrane life is estimated to range from six months to three years, depending on the use of the system. Down time for

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flushing or cleaning is on the order of 2 hours as often as once each week; a substantial portion of maintenance time must be spent on cleaning any prefilters installed ahead of the reverse osmosis unit.

Solid Waste Aspects: In a closed loop system utilizing RO there is a constant recycle of concentrate and a minimal amount of solid waste. Prefiltration eliminates many solids before they reach the module and helps keep the buildup to a minimum. These solids require proper disposal.

Demonstration Status. There are presently at least one hundred reverse osmosis waste water applications in a variety of industries. In addition to these, there are thirty to forty units being used to provide pure process water for several industries. Despite the many types and configurations of membranes, only the spiral-wound cellulose acetate membrane has had widespread success in commercial applications. Reverse osmosis is used at one battery plant to treat process wastewater for reuse as boiler feedwater.

Sludge Bed Drying

As a waste treatment procedure, sludge bed drying is employed to reduce the water content of a variety of sludges to the point where they are amenable to mechanical collection and removal to landfill. These beds usually consist of 15 to 45 cm (6 to 18 in.) of sand over a 30 cm (12 in.) deep gravel drain system made up of 3 to 6 mm (1/8 to 1/4 in.) graded gravel overlying drain tiles. Figure VII-19 shows the construction of a drying bed.

Drying beds are usually divided into sectional areas approximately 7.5 meters (25 ft) wide x 30 to 60 meters (100 to 200 ft) long. The partitions may be earth embankments, but more often are made of planks and supporting grooved posts.

To apply liquid sludge to the sand bed, a closed conduit or a pressure pipeline with valved outlets at each sand bed section is often employed. Another method of application is by means of an open channel with appropriately placed side openings which are controlled by slide gates. With either type of delivery system, a concrete splash slab should be provided to receive the falling sludge and prevent erosion of the sand surface.

Where it is necessary to dewater sludge continuously throughout the year regardless of the weather, sludge beds may be covered with a fiberglass reinforced plastic or other roof. Covered drying beds permit a greater volume of sludge drying per year in most climates because of the protection afforded from rain or snow and because of more efficient control of temperature. Depending on the climate, a

combination of open and enclosed beds will provide maximum utilization of the sludge bed drying facilities.

Application and Performance.   Sludge drying beds are a means of dewatering sludge from clarifiers and thickeners. They are widely used both in municipal and industrial treatment facilities.

Dewatering of sludge on sand beds occurs by two mechanisms: filtration of water through the bed and evaporation of water as a result of radiation and convection. Filtration is generally complete in one to two days and may result in solids concentrations as high as 15 to 20 percent. The rate of filtration depends on the drainability of the sludge.

The rate of air drying of sludge is related to temperature, relative humidity, and air velocity. Evaporation will proceed at a constant rate to a critical moisture content, then at a falling rate to an equilibrium moisture content. The average evaporation rate for a sludge is about 75 percent of that from a free water surface.

Advantages and Limitations.   The main advantage of sludge drying beds over other types of sludge dewatering is the relatively low cost of construction, operation, and maintenance.

Its disadvantages are the large area of land required and long drying times that depend, to a great extent, on climate and weather.

Operational Factors.   Reliability: Reliability is high with favorable climactic conditions, proper bed design and care to avoid excessive or unequal sludge application.   If climatic conditions in a given area are not favorable for adequate drying, a cover may be necessary.

Maintainability: Maintenance consists basically of periodic removal of the dried sludge. Sand removed from the drying bed with the sludge must be replaced and the sand layer resurfaced.

The resurfacing of sludge beds is the major expense item in sludge bed maintenance, but there are other areas which may require attention. Underdrains occasionally become clogged and have to be cleaned. Valves or sludge gates that control the flow of sludge to the beds must be kept watertight. Provision for drainage of lines in winter should be provided to prevent damage from freezing. The partitions between beds should be tight so that sludge will not flow from one compartment to another.   The outer walls or banks around the beds should also be watertight.

Solid Waste Aspects: The full sludge drying bed must either be abandoned or the collected solids must be removed to a landfill. These solids contain whatever metals or other materials were settled

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in the clarifier. Metals will be present as hydroxides, oxides, sulfides, or other salts. They have the potential for leaching and contaminating ground water, whatever the location of the semidried solids. Thus the abandoned bed or landfill should include provision for runoff control and leachate monitoring.

Demonstration Status. Sludge beds have been in common use in both municipal and industrial facilities for many years. However, protection of ground water from contamination is not always adequate.

Ultrafiltration

Ultrafiltration (UF) is a process which uses semipermeable polymeric membranes to separate emulsified or colloidal materials suspended in a liquid phase by pressurizing the liquid so that it permeates the membrane. The membrane of an ultrafilter forms a molecular screen which retains molecular particles based on their differences in size, shape, and chemical structure. The membrane permits passage of solvents and lower molecular weight molecules. At present, an ultrafilter is capable of removing materials with molecular weights in the range of 1,000 to 100,000 and particles of comparable or larger sizes.

In an ultrafiltration process, the feed solution is pumped through a tubular membrane unit. Water and some low molecular weight materials pass through the membrane under the applied pressure of 10 to 100 psig. Emulsified oil droplets and suspended particles are retained, concentrated, and removed continuously. In contrast to ordinary filtration, retained materials are washed off the membrane filter rather than held by it. Figure VII-25 represents the ultrafiltration process.

Application and Performance. Ultrafiltration has potential application to battery manufacturing for separation of oils and residual solids from a variety of waste streams. In treating battery manufacturing wastewater its greatest applicability would be as a polishing treatment to remove residual precipitated metals after chemical precipitation and clarification. Successful commercial use, however, has been primarily for separation of emulsified oils from wastewater. Over one hundred such units now operate in the United States, treating emulsified oils from a variety of industrial processes. Capacities of currently operating units range from a few hundred gallons a week to 50,000 gallons per day. Concentration of oily emulsions to 60 percent oil or more are possible. Oil concentrates of 40 percent or more are generally suitable for incineration, and the permeate can be treated further and in some cases recycled back to the process. In this way, it is possible to eliminate contractor removal costs for oil from some oily waste streams.

The following test data indicate ultrafiltration performance (note that UF is not intended to remove dissolved solids):

Table VII-23

ULTRAFILTRATION PERFORMANCE

Parameter	Feed (mg/l)	Permeate (mg/l)
Oil (freon extractable)	1230	4
COD	8920	148
TSS	1380	13
Total Solids	2900	296

The removal percentages shown are typical, but they can be influenced by pH and other conditions.

The permeate or effluent from the ultrafiltration unit is normally of a quality that can be reused in industrial applications or discharged directly. The concentrate from the ultrafiltration unit can be disposed of as any oily or solid waste.

Advantages and Limitations. Ultrafiltration is sometimes an attractive alternative to chemical treatment because of lower capital equipment, installation, and operating costs, very high oil and suspended solids removal, and little required pretreatment. It places a positive barrier between pollutants and effluent which reduces the possibility of extensive pollutant discharge due to operator error or upset in settling and skimming systems. Alkaline values in alkaline cleaning solutions can be recovered and reused in process.

A limitation of ultrafiltration for treatment of process effluents is its narrow temperature range (18° to 30°C) for satisfactory operation. Membrane life decreases with higher temperatures, but flux increases at elevated temperatures. Therefore, surface area requirements are a function of temperature and become a tradeoff between initial costs and replacement costs for the membrane. In addition, ultrafiltration cannot handle certain solutions. Strong oxidizing agents, solvents, and other organic compounds can dissolve the membrane. Fouling is sometimes a problem, although the high velocity of the wastewater normally creates enough turbulence to keep fouling at a minimum. Large solids particles can sometimes puncture the membrane and must be removed by gravity settling or filtration prior to the ultrafiltration unit.

Operational Factors. Reliability: The reliability of an ultrafiltration system is dependent on the proper filtration, settling or other treatment of incoming waste streams to prevent damage to the membrane. Careful pilot studies should be done in each instance to determine necessary pretreatment steps and the exact membrane type to be used.

Maintainability: A limited amount of regular maintenance is required for the pumping system. In addition, membranes must be periodically changed. Maintenance associated with membrane plugging can be reduced by selection of a membrane with optimum physical characteristics and sufficient velocity of the waste stream. It is often necessary to occasionally pass a detergent solution through the system to remove an oil and grease film which accumulates on the membrane. With proper maintenance membrane life can be greater than twelve months.

Solid Waste Aspects: Ultrafiltration is used primarily to recover solids and liquids. It therefore eliminates solid waste problems when the solids (e.g., paint solids) can be recycled to the process. Otherwise, the stream containing solids must be treated by end-of-pipe equipment. In the most probable applications within the battery manufacturing category, the ultrafilter would remove hydroxides or sulfides of metals which have recovery value.

Demonstration Status. The ultrafiltration process is well developed and commercially available for treatment of wastewater or recovery of certain high molecular weight liquid and solid contaminants.

Vacuum Filtration

In wastewater treatment plants, sludge dewatering by vacuum filtration generally uses cylindrical drum filters. These drums have a filter medium which may be cloth made of natural or synthetic fibers or a wire-mesh fabric. The drum is suspended above and dips into a vat of sludge. As the drum rotates slowly, part of its circumference is subject to an internal vacuum that draws sludge to the filter medium. Water is drawn through the porous filter cake to a discharge port, and the dewatered sludge, loosened by compressed air, is scraped from the filter mesh. Because the dewatering of sludge on vacuum filters is relativley expensive per kilogram of water removed, the liquid sludge is frequently thickened prior to processing. A vacuum filter is shown in Figure VII-16.

Application and Performance. Vacuum filters are frequently used both in municipal treatment plants and in a wide variety of industries. They are most commonly used in larger facilities, which may have a thickener to double the solids content of clarifier sludge before vacuum filtering.

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The function of vacuum filtration is to reduce the water content of sludge, so that the solids content increases from about 5 percent to about 30 percent.

Advantages and Limitations. Although the initial cost and area requirement of the vacuum filtration system are higher than those of a centrifuge, the operating cost is lower, and no special provisions for sound and vibration protection need be made. The dewatered sludge from this process is in the form of a moist cake and can be conveniently handled.

Operational Factors. Reliability: Vacuum filter systems have proven reliable at many industrial and municipal treatment facilities. At present, the largest municipal installation is at the West Southwest waste water treatment plant of Chicago, Illinois, where 96 large filters were installed in 1925, functioned approximately 25 years, and then were replaced with larger units. Original vacuum filters at Minneapolis-St. Paul, Minnesota now have over 28 years of continuous service, and Chicago has some units with similar or greater service life.

Maintainability: Maintenance consists of the cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the equipment. Experience in a number of vacuum filter plants indicates that maintenance consumes approximately 5 to 15 percent of the total time. If carbonate buildup or other problems are unusually severe, maintenance time may be as high as 20 percent. For this reason, it is desirable to maintain one or more spare units.

If intermittent operation is used, the filter equipment should be drained and washed each time it is taken out of service. An allowance for this wash time must be made in filtering schedules.

Solid Waste Aspects: Vacuum filters generate a solid cake which is usually trucked directly to landfill. All of the metals extracted from the plant wastewater are concentrated in the filter cake as hydroxides, oxides, sulfides, or other salts.

Demonstration Status. Vacuum filtration has been widely used for many years. It is a fully proven, conventional technology for sludge dewatering. Vacuum filtration is used in two battery manufacturing plants for sludge dewatering.

IN-PROCESS POLLUTION CONTROL TECHNIQUES

Introduction

In general, the most cost-effective pollution reduction techniques available to any industry are those which prevent completely the entry of pollutants into process wastewater or reduce the volume of wastewater requiring treatment. These "in-process" controls can increase treatment effectiveness by presenting the pollutants to treatment in smaller, more concentrated waste streams from which they can be more completely removed, or by eliminating pollutants which are not readily removed or which interfere with the treatment of other pollutants. They also frequently yield economic benefits both in decreased waste treatment costs and in decreased consumption or recovery of process materials. Process water use in battery manufacturing provides many opportunities for in-process control and, as Table VII-24 shows, some in-process control measures have been implemented by many battery manufacturing facilities. The wide range in process water use and wastewater discharge exhibited by battery manufacturing plants (as shown in the data presented in Section V) reflects the present variability of in-process control at these facilities.

While many in-process pollution control techniques are of general significance, specific applications of these techniques vary among different battery manufacturing subcategories. In addition, some in-process control techniques apply only to specific processing steps.

Generally Applicable In-Process Control Techniques

Techniques which may be applied to reduce pollutant discharges from most battery manufacturing subcategories include waste segregation, water recycle and reuse, water use reduction, process modification, and plant maintenance and good housekeeping. Effective in-process control at most plants will entail a combination of several techniques. Frequently, the practice of one in-process control technique is required for the successful implementation of another. For example, waste segregation is frequently a prerequisite for the extensive practice of wastewater recycle or reuse.

Waste Segregation - The segregation of wastewater streams is a key element in effective pollution control. Separation of non-contact cooling water from process wastewater prevents dilution of the process wastes and maintains the purity of the non-contact stream for subsequent reuse or discharge. Similarly, the segregation of process waste streams differing significantly in their chemical characteristics can increase effectiveness and reduce treatment costs.

Segregation of specific process wastewater streams is common in battery manufacturing plants.

Mixing process wastewater with non-contact cooling water generally has an adverse effect on both performance and treatment costs. The resultant waste stream is usually too contaminated for continued reuse in non-contact cooling, or for discharge without treatment. The increased volume of wastewater increases the size and cost of treatment facilities and lowers removal effectiveness. Thus a plant which segregates non-contact cooling water and other nonprocess waters from process wastewater can generally achieve a lower mass discharge of pollutants while incurring lower treatment costs.

Battery manufacturing facilities commonly produce multiple process wastewater streams having significantly different chemical characteristics; some are high in toxic metals; some may contain primarily suspended solids; and others may be quite dilute. Wastewater from a specific process or operation usually contains only a few of the many pollutants generated at a particular site. Segregation of these individual process waste streams may allow reductions in treatment costs and pollutant discharges.

The segregation of dilute process waste streams from those bearing high pollutant loads often allows further process use of the dilute streams; they may be recycled to the process from which they were discharged; or they may be suitable for use in another process. Sometimes, the dilute process waste streams are suitable for incorporation into the product.

Segregation of waste streams containing high levels of suspended solids allows separate treatment of these streams in relatively inexpensive settling systems. Often the clarified wastewater is suitable for further process use and both pollutant loads and the wastewater volume requiring further treatment are reduced. Segregation and separate treatment of these waste streams may yield an additional economic benefit to the plant by allowing increased recovery of process materials. Because the solids borne by wastewater from a specific process operation are primarily composed of materials used in that operation, sludges resulting from separate settling of these streams may frequently be reclaimed for use in the process with little or no processing. This technique presently is used to recover materials used in processing pasted, electrodeposited and impregnated electrodes at battery manufacturing plants.

Wastewater Recycle and Reuse - The recycle or reuse of process wastewater is effective in the reduction of both pollutant discharges and treatment costs. The term recycle is used to designate the return of process wastewater to the process or processes from which it originated while reuse refers to the use of wastewater from one

process in another. Both recycle and reuse of process wastewater are presently practiced at battery manufacturing plants although recycle is more extensively used. The most frequently recycled waste streams include air pollution control scrubber water, and wastewater from equipment and area cleaning. Numerous other process wastewater streams from battery manufacturing activities may also be recycled or reused.

Both recycle and reuse are frequently possible without treatment of the wastewater; process pollutants present in the wastewater stream are often tolerable (or occasionally even beneficial) for process use. Recycle or reuse in these instances yields cost savings by reducing the volume of wastewater requiring treatment. Where treatment is required for recycle or reuse, it is frequently considerably simpler than the treatment necessary to achieve effluent quality suitable for release to the environment. Treatment prior to recycle or reuse observed in present practice is generally restricted to simple settling or neutralization. Since these treatment practices are less costly than those used prior to discharge, economic as well as environmental benefits are usually realized. In addition to these "in-process" recycle and reuse practices, some plants are observed to return part or all of the treated effluent from an end-of-pipe treatment system for further process use.

Recycle can usually be implemented with minimal complications and expense; treatment requirements are likely to be least for recycle; and piping to remote locations in the plant is not generally required.

Common points of wastewater recycle in present practice incude air pollution control scrubbers, and equipment and area wash water. In addition, recycle of wastewater is observed in some product rinsing operations and in contact cooling.

The rate of water use in wet scrubbers is determined by the requirement for adequate contact with the air being scrubbed and not by the mass of pollutants to be removed. As a result wastewater streams from once-through scrubbers are characteristically very dilute and high in volume. These streams may usually be recycled extensively without treatment with no deleterious effect on scrubber performance. Limited treatment such as neutralization where acid fumes are scrubbed can significantly increase the practical recycle rate.

Water used in washing process equipment and production floor areas frequently serves primarily to remove solid materials and is often treated by settling and recycled. This practice is especially prevalent at lead subcategory plants, but is observed in other subcategories as well. In some instances the settled solids as well as the clarified wastewater are returned for use in the process. The extent of recycle of these waste streams is characteristically very

high and in many cases no wastewater is discharged from the recycle loop.

Water used in product rinsing is also recirculated in some cases, especially from battery rinse operations. This practice is ultimately limited by the concentrations of materials rinsed off the product in the rinsewater. Wastewater from contact cooling operations also may contain low concentrations of pollutants which do not interfere with recycle of these streams. In some cases recycle of contact cooling water with no treatment is observed while in others provisions for heat removal in cooling towers is required. Where contact cooling water becomes heavily contaminated with acid, neutralization may be required to minimize corrosion.

Water used in vacuum pump seals and ejectors commonly becomes contaminated with process pollutants. The level of contaminants in these high volume waste streams is sometimes low enough to allow recycle to the process. With minimal treatment, a high degree of recycle of wastewater from contact cooling streams may require provisions for neutralization or removal of heat.

The extent of recycle possible in most process water uses is ultimately limited by the increasing concentrations of dissolved solids in the water. The build-up of dissolved salts generally necessitates some small discharge or "blowdown" from the process to treatment. In some cases, the rate of addition of dissolved salts may be sufficiently low to be balanced by removal of dissolved solids in water entrained in settled solids. In these cases complete recycle with no discharge can be achieved. In other instances, the contaminants which buildup in the recycle loop may be compatible with another process operation, and the blowdown may be reused in another process. One example of this is observed in lead subcategory scrubber, battery rinse, and contact cooling wastes which become increasingly laden with sulfuric acid and lead during recycle. Small volumes bled from these recycle loops may be used in diluting concentrated acid to prepare battery electrolyte as observed at some existing facilities.

Water Use Reduction - The volume of wastewater discharged from a facility or specific process operation may be reduced simply by eliminating excess flow and unnecessary water use. Often this may be accomplished with no change in the manufacturing process or equipment and without any capital expenditure. A comparison of the volumes of process water used in and discharged from equivalent process operations at different battery manufacturing plants or on different days at the same plant indicates numerous opportunities for water use reductions. Additional reductions in process water use and discharge may be achieved by modifications to process techniques and equipment.

Many production units in battery manufacturing facilities were observed to operate intermittently or at highly variable production rates. The practice of shutting off process water flow during periods when the unit is not operating and of adjusting flow rates during periods of low production can prevent much unnecessary water use. Water may be shut off and controlled manually or through automatically controlled valves. Manual adjustment involves the human factor and has been found to be somewhat unreliable in practice; production personnel may fail to turn off manual valves when production units are shut down and have been observed to increase water flow rates to maximum levels "to insure good operation" regardless of production activity. Automatic shut off valves may be used to turn off water flows when production units are inactive. Automatic adjustment of flow rates according to production levels requires more sophisticated control systems incorporating production rate sensors.

Observations and flow measurements at visited battery manufacturing plants indicate that automatic flow controls are rarely employed. Manual control of process water use is generally observed in process rinse operations, and little or no adjustment of these flows to production level was practiced. The present situation is exemplified by a rinse operation at one site where the daily average production normalized discharge flow was observed to vary from 90 to 1200 l/kg over a three day span. Thus, significant reductions in pollutant discharges can be achieved by the application of flow control at this site at relatively little cost.

Additional flow reductions may be achieved by the implementation of more effective water use in some process operations. These measures generally require the purchase or modification of some process equipment and involve larger capital investment than the simple flow control measures discussed above. The most significant areas for improvement in water use effectiveness are in rinsing operations and in equipment and area clean-up. Under some circumstances, process water use in removing excess materials from electrode stock and in washing batteries may be eliminated without any significant change in the manufacturing process or the final product.

Rinsing is a common operation in the manufacture of batteries, and a major source of wastewater discharge at most plants. Efficient rinsing implies the removal of the greatest mass of material in the smallest volume of water. It is achieved by ensuring that the material removed is distributed uniformly through the rinse water. (The high porosity of many of the electrode structures makes the achievement of uniform mixing difficult necessitating long product residence times and high mixing rates in rinses). Rinsing efficiency is also increased by the use of multi-stage and countercurrent rinses. Multi-stage rinses reduce the total rinse water requirements by allowing the removal of most of the contaminants in more concentrated

waste streams with only the final stage rinse diluted to the levels required for final product purity. In a counter-current rinse, dilute wastewater from each rinse stage is reused in the preceding rinse stage and all of the contaminants are discharged in a single concentrated waste stream.

Equipment and area clean-up practices observed at battery manufacturing facilities vary widely. While some facilities employ completely dry clean-up techniques others use water with varying degrees of efficiency. The practice of "hosing down" equipment and production areas generally represents a very inefficient use of water, especially when hoses are left running during periods when they are not used. Alternative techniques which use water more efficiently include floor wash machines and bucket and sponge or bucket and mop techniques as observed at some facilities.

A major factor necessitating battery washing in many cases is electrolyte spillage on the battery case during filling. This spillage and subsequent wash requirements are maximized when batteries are filled by immersion or by "overfill and withdraw." Water use in battery washing may be significantly reduced by the use of filling techniques and equipment which add the correct amount of electrolyte to the battery without overfilling and which minimize drips and spills on the battery case. These electrolyte addition techniques and the production of finished batteries with little or no battery washing are observed at numerous plants in the category.

Additional reduction in process water use and wastewater discharge may be achieved by the substitution of dry air pollution control devices such as baghouses for wet scrubbers where the emissions requiring control are amenable to these techniques.

Process Modification - There are numerous process alternatives for the manufacture of batteries in most of the battery manufacturing subcategories, and the alternatives frequently differ significantly in the quantity and quality of wastewater produced. Most process modifications which may be considered as techniques for reducing pollutant discharge are specific to individual subcategories and are discussed in subsequent sections. In general, process modifications considered deal with changes in electrolyte addition techniques as discussed previously and changes in electrode formation processes. In addition, changes in amalgamation procedures and improvements in process control to reduce rework requirements are viable techniques to reduce wastewater discharge at some sites.

One process modification applicable to several subcategories is the substitution of alternative formulations for cell wash materials containing chromate and cyanide. This substitution will eliminate

these pollutants from process wastewater at the plants which presently use them.

Plant Maintenance and Good Housekeeping - Housekeeping practices are particularly significant for pollution control at battery manufacturing facilities. Large quantities of toxic materials used as active materials in battery electrodes are handled and may be spilled in production areas. The use of water in cleaning up these materials may contribute significantly to wastewater discharges at some facilities.

Maintenance practices are important in eliminating unnecessary spills and leaks and in reducing contamination of non-contact cooling water. Examples of the impact of faulty maintenance were observed in the contamination of non-contact cooling water in a leaking ball mill cooling jacket at one lead subcategory facility and in the use of excess water in hosing down a malfunctioning amalgamation blender. In both cases, the volume of wastewater requiring treatment and losses of process materials were increased resulting in increased treatment and manufacturing process costs as well as increased pollutant discharges.

Good housekeeping encompasses a variety of plant design and operating practices which are important for efficient plant operation and worker hygiene and safety as well as for water pollution control. These include:

- Floor maintenance and treatment in areas where pollutant materials are handled to minimize cracks and pores in which spilled materials may lodge. This reduces the volume of water required to clean up spills and increases the efficiency of dry cleanup techniques.

- Preventing drips and spills and collecting those which cannot be avoided, especially in electrolyte addition areas. Isolating the materials rather than letting them run over equipment and floor surfaces can greatly reduce wash-down requirements and also allow the collected materials to be returned for process use instead of being discharged to waste treatment.

- Reduction in spillage during bulk handling by provision for dust control and for rapid dry clean-up of spilled materials.

Cadmium Subcategory

Cadmium subcategory manufacturing involves a wide variety of process water uses in active material preparation, electrode processing and rinses, cell washing, equipment and area washing, and air pollution control. Consequently, many different in-process control techniques

are applicable. These include waste segregation, material recovery, process water recycle and reuse, water use control (reduction), and process modification possibilities.

Waste Segregation - The segregation of wastewater streams from individual process operations is presently practiced by some manufacturers in this subcategory. Segregation of specific waste streams is useful in allowing recycle and reuse and in making the recovery of some process materials feasible. Waste streams segregated for these purposes include wet air pollution control scrubber discharges which are segregated for recycle, formation process solutions which are segregated for reuse in formation or in other process operations, and waste streams from impregnation, electrodeposition and wet plate cleaning or brushing which are segregated to allow material recovery. Segregation of process wastes is not practiced for end-of-pipe treatment in this subcategory because all process waste streams are amenable to treatment by the same technologies. The segregation of noncontact cooling and heating water from process wastewater is essential for effective removal of process pollutants in end-of-pipe treatment, and it is presently practiced at most plants in the subcategory. Many plants recirculate noncontact cooling water through cooling towers.

Material Recovery - Cadmium or nickel hydroxide particles, formed during impregnation or electrodeposition do not adhere to the electrode structure and are removed in rinse or process discharges. If the discharges from cathode and anode processes are segregated, these particles may be recovered by settling to yield separate sludges rich in cadmium or nickel. The metal values may be recovered from these sludges. This practice, presently employed in the subcategory, yields an economic return from recovered cadmium and nickel; reduces the waste loads flowing to treatment; and reduces the quantities of toxic metal sludge requiring disposal.

Wastewater Recycle and Reuse - Process wastewater streams produced in this subcategory which are presently recycled or suitable for recycle include wet scrubber discharges, wastewater from cleaning impregnated electrodes or electrode stock and process solutions used in material deposition and electrode formation. Recycle of these waste streams is presently practiced and yields large reductions in process wastewater flow.

Air pollution control scrubbers are employed to control emissions of acid fumes and toxic metals (cadmium and nickel) from process solutions used in electrodeposition, impregnation, active material preparation and material recovery operations. Recycle of water used in these scrubbers is common but not universal. Of six wet scrubbers reported in use at plants in this subcategory, five employ extensive recycle of the scrubber water. Discharge flow rates from recirculated

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scrubber systems were as low as 1.1 l/hr, while the non-recirculated scrubber had a discharge of 9538 l/hr. In many cases, caustic solutions are used in the scrubbers and recirculated until neutralized by the collected acid fumes. This practice results in the presentation to treatment of a concentrated small volume discharge from which pollutants may be effectively removed.

Wet cleaning of impregnated electrodes or electrode stock results in large volumes of wastewater bearing high concentrations of particulate nickel or cadmium hydroxide. This wastewater may be treated by settling and recycled for continued use in the cleaning operation. Since the primary contaminant in this waste stream is suspended solids, a very high degree of recycle after settling is practical. Recycle of this wastewater stream following settling to remove suspended solids is practiced at one facility with wastewater discharged only once per month. The volume of wastewater from this process after recycle is only 4.8 l/kg. This may be compared to a discharge volume of 108 l/kg observed at another facility which does not recycle electrode cleaning wastewater.

Water used in washing process equipment and production floor areas in this subcategory also becomes contaminated primarily with suspended solids. The wastewater may be treated by settling and recycled for further use in floor and equipment wash operations. Recycle of these waste streams will allow effective maintenance of equipment and floor areas with little or no process wastewater discharge.

Process solutions used in material deposition and electrode formation are extensively reused at most plants and represent a minimal contribution to the total wastewater flow. Reuse of these process solutions significantly reduces pollutant loads discharged to waste treatment and also yields economic benefits in reduced consumption of process chemicals.

Water Use Control and Reduction - Large volumes of process water are used in rinsing at cadmium subcategory plants. On site observations at several facilities, and analysis of flow rate information from other sites indicate that effective control of water use in these operations is not achieved, and that substantial reductions from present discharge rates may be attained by instituting effective water use control. The lack of effective water use control in these operations is demonstrated by the wide range of flow rates among facilities and on different days at individual facilities. Practices contributing to excessive water use and discharge in rinsing were observed during sampling visits at four cadmium subcategory plants. At one plant, for example, measured rinse flow was observed to be about 25 percent greater than the values reported in the dcp, and production was about 50 percent less than that reported. The wastewater discharge per unit of production was approximately three

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times the value indicated by dcp information. At this site rinsing was practiced on a batch basis, and the rinse cycle included an overflow period after the rinse tank was filled with water. The length of this overflow period was observed to vary arbitrarily and was frequently lengthened considerably when the water was left running through coffee breaks and meals. Similar rinse flow variability was observed at other plants.

Flows reported in dcp's for wastewater discharge from process rinses associated with anode and nickel cathode electrodeposition and impregnation are attainable by implementation of rinse flow control at all sites. This can be achieved through the use of automatic shut-offs which will close water supply valves when the process line is not running and adjustment of rinse flows when production rates vary.

Further reductions may be achieved by application of multi-stage countercurrent rinse techniques. While multi-stage rinses are common in the subcategory, countercurrent rinsing is practiced only sometimes and is not accompanied by effective water use control. Implementation of countercurrent rinses in this subcategory will differ since rinsing equipment and techniques are observed to vary.

Another technique used to reduce process flow rates is the use of dry air pollution control equipment such as bag houses. Two facilities reported using bag houses to control dust emissions caused by processing dry materials.

Wastes from electrolyte preparation and addition to cells result from equipment washing and from drips and spills of electrolyte. Collection of electrolyte drips in filling operations and reusing this material in filling cells can aid in eliminating this waste stream. Wastewater from washing electrolyte preparation and addition equipment is reported by only a few plants. Other facilities evidently use dry equipment maintenance procedures or recycle equipment wash water.

Floor cleaning at cadmium subcategory plants may also be accomplished with or without the use of process water, and where water is used the efficiency of use varies. Efficient use of floor wash water may substantially reduce wastewater discharge at some plants as indicated by the comparison of reported normalized discharge flows for this activity which range from 0.25 to 33.4 liters per kilogram of finished cells produced. Dry floor clean-up is a viable option in this subcategory since most of the materials requiring removal from production floor areas are dry solids. Seven active plants in the subcategory reported no process wastewater from washing floors and apparently employ dry floor cleaning techniques. Only two plants reported wastewater discharge from floor cleaning.

Process Modification - Numerous manufacturing processes for the production of cadmium subcategory batteries are observed. They vary widely in the volume and characteristics of process wastewater produced. Many of the process variations, however, correspond to variations in battery performance characteristics and therefore may not be suitable for use as bases for pollutant discharge reductions throughout the subcategory. For example, the manufacture of pasted and pocket plate powder electrodes is observed to yield significantly lower wastewater discharges than the production of sintered, impregnated electrodes, but the current and power densities attained in pocket plate electrodes are lower than those in sintered, impregnated electrodes. Since the products of these two process alternatives are not completely equivalent, process modification by substitution of one for the other may not be a viable basis for effluent limitations. There are however, some observed or potential process modifications which can result in reduced pollutant discharges without significantly affecting product characteristics. These include modifications in electrode formation practices, and improvements in process control on active material preparation operations.

In-case formation appears to be feasible without any apparent impact on battery performance characteristics. This practice which eliminates wastewater discharge from spent formation solutions and from post formation rinses could be applied to reduce pollutant discharges.

In the production of cadmium powder for use in battery manufacturing, the product is rinsed after precipitation. Improved process control of the precipitation step and of rinsing would reduce the volume of wastewater from this operation by approximately 40 percent.

Calcium Subcategory

Process water use in this subcategory is very limited. Consequently, the opportunities for in-process controls significantly reducing water use or wastewater discharge are correspondingly limited. Water used in the disposal of calcium scrap may be reduced by limiting the amount of scrap produced and by limiting the amount of water used per unit weight of scrap disposed. Alternatively, this waste source may be eliminated altogether by allowing the calcium to react with atmospheric moisture and disposing of the resultant calcium hydroxide as a solid waste.

Lead Subcategory

Process water uses in lead subcategory plants include contact cooling, electrode rinsing, battery washing, equipment and area washing, and air pollution control scrubbers. Wastewater discharges from these

sources may be reduced or eliminated by application of a variety of in-process control techniques. Most of the identified applicable in-process controls are presently in use at one or more plants in the subcategory. Some, such as pasting area wash down recirculation, scrubber discharge recycle, use of dry air pollution control techniques, and elimination of contact cooling water discharges, are extensively practiced.

Waste Segregation - The segregation of wastewater streams from different process operations is a vital part of effective pollution control at lead subcategory plants. Wastewater from pasting area and equipment wash-down is commonly segregated from other process waste streams because it carries extremely high concentrations of recoverable suspended leady oxide particles. Scrubber discharges and battery rinse water are segregated to allow recycle or reuse. In addition acid used in forming batteries is kept separate from process wastewater at essentially all sites so that it can be reused in formation. Battery wash water may also be segregated when it contains detergents or significant quantities of oil and grease.

Material Recovery - The recovery of particulate lead oxide from paste preparation and application wastes is a common practice at lead subcategory plants which reduces both wastewater pollutant loads and the mass of solid waste requiring disposal. This material is generally recovered by settling from the equipment and area wash water as a part of treatment of this stream for recycle. Approximately 30 percent of lead subcategory plants reuse the settled solids directly in paste formulation.

Wastewater Recycle and Reuse - Process wastewater streams which are presently recycled or reused in this subcategory include pasting area wash-down, scrubber wastewater, battery rinse water and contact cooling water. In addition, some plants in the subcategory return treated effluent water for reuse in the manufacturing process. While the extent of recycle and reuse varies from plant to plant, numerous examples in present practice show that these techniques can be highly effective in reducing wastewater volume and pollutant discharges.

Equipment and floor wash water recycle from paste preparation and application areas is widespread. These recycle systems commonly include settling for suspended solids removal and operate as completely closed loop systems resulting in the complete elimination of process wastewater discharge from this source. Water from the recirculated wash-down stream may be used in the paste mixing operation and ultimately be evaporated from the plates in drying and curing. Some water is also entrained with the solids settled from the wastewater. As a result, this operation often has a net negative water balance and requires the introduction of fresh make-up or of wastewater from another process which is suitable for reuse in this

way. Fifty-five plants in the subcategory reported the reuse of past-ing area wastewater.

Wet scrubbers are used for the control of sulfuric acid fumes and mist resulting from electrolyte preparation and battery formation processes. Significant recycle of these scrubber streams is possible before acid concentrations become high enough to impair fume scrubbing efficiency. If no reagents are added the concentrated scrubber discharge after recycle is suitable for use in electrolyte formulation. Alternatively, caustic solutions may be used in the scrubber allowing a still higher degree of recycle, and reducing the volume of discharge to very low values.

Rinsing of batteries is performed primarily to remove sulfuric acid spilled on the outside of the battery case. If the acid results from overfilling the battery or dumping electrolyte from the battery, or if it has previously been used in formation it will contain lead as well. The wastewater from rinsing the batteries will consequently contain acid, lead, and other contaminants from process conveyors, racks or floors over which the acidic rinse water is permitted to run. Failure to segregate the battery rinse water from battery wash water in which detergent formulations are used may also result in the presence of detergents in this waste stream.

The rinse water characteristically becomes only slightly contaminated in a single use and it may be recycled for use in rinsing several times before acidity becomes too high for effective rinsing. When the acidity becomes too high for further use in rinsing, the rinse water may be reused in pasting area washdown or in electrolyte preparation. Use in acid cutting for electrolyte, however, requires that levels of contaminants, especially iron, be generally low. This may be achieved by care in rinsing to prevent contact of the corrosive rinse water with exposed iron and steel surfaces or contaminated floor areas. Alternatively, the spent rinse water may be treated to remove iron prior to use in acid cutting. Nineteen plants reported the reuse of rinse water. Five of these plants treat process wastewater before reusing in the rinse operations. Typically treatment involves pH adjustment and settling to remove particulates before the wastewater is reused for rinsing purposes.

Contact cooling water used in battery formation may be recirculated extensively as described for battery rinse water. In this case, the rate of acid build-up in the recycled stream should be quite low, but the water may require cooling in a cooling tower for continued use. A small bleed from the recycle loop is sufficient to control the levels of acid and lead in the water, and the bleed stream may be reused in acid cutting, pasting area washdown or paste preparation. Caustic may be added to the recycled water to maintain an alkaline or neutral pH and prevent corrosion or safety hazards.

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Iron accumulating in the contact cooling water as a result of the contact of acid water with production racks or conveyors may be an obstacle to reuse of the bleed stream. This problem may be resolved either by treatment to remove the iron by chemical precipitation or by the prevention of contamination through the use of epoxy coatings on racks or conveyors and control of contact cooling water flow patterns.

Wastewater from vacuum pump seals and ejectors used in dehydrating formed plates for use in dehydrated batteries also may be extensively recycled. Since the level of contamination in waste streams from this use is low, recycle may drastically reduce the high volume discharges presently produced at some facilities.

Discharges from steam curing processes and wastewater from general floor area and equipment washdown can be retained for reuse in acid cutting operations, along with bleed streams from recirculation systems used for wet scrubbers, contact cooling, or battery rinsing.

Process Modification - While there are numerous process alternatives for many operations in the manufacture of batteries in the lead subcategory, the alternatives which are most significant in their impact on wastewater discharge are in the processes for formation of the battery electrodes. In addition, differences in plate curing techniques also influence process wastewater discharge to some extent, as does the addition of a rinse prior to battery washing.

The greatest differences in wastewater discharge in this subcategory result from the difference between dehydrated plate battery manufacture and wet or damp battery manufacture. This difference in formation procedures also results in significant differences in product characteristics as discussed in Section V.

The major water uses in the formation and dehydration of electrodes for dehydrated plate batteries are in rinsing and dehydrating the formed plates. Thorough rinsing is required to remove residual sulfuric acid from the formed plates and characteristically produces a large volume of wastewater. Water is used in dehydration of the plates either in ejectors used to maintain a vacuum and enhance drying or in water seals or vacuum pumps used for the same purpose.

While rinsing and drying the plates is an indispensable part of the formation process, plate dehydration can be accomplished without the use of ejector or vacuum pump seal water. Oven drying without process water use for the dehydration of plates was observed, and approximately 50 percent of all plants producing dehydrated plate batteries showed no wastewater discharge from dehydration of the plates. Oxidation of negative plates during the heat drying process may be controlled by the introduction of inert or reducing atmospheres into the drying ovens.

Several distinct formation procedures are employed in the production of wet and damp batteries resulting in significant variations in wastewater discharge flow rate. In addition to the differences between wet and damp battery formation, formation processes differ in the concentration of the formation electrolyte and in the rate of charging. All of these variations are observed to have an influence on wastewater discharge from the formation process and from the plant as a whole.

The formation of damp batteries concludes with dumping the formation acid from the battery which is shipped empty. Although no process wastewater is directly discharged from the electrolyte dumping operations, the production of damp batteries influences wastewater discharge in two ways. First, the practice of dumping acid from the batteries increases the amount of acid contamination on the outside of the battery case. This effect, however, is also observed in double fill closed formation. Second, since the batteries are shipped dry, electrolyte usage on-site is significantly reduced. This reduces the amount of water used in acid cutting and therefore the potential amount of process wastewater which may be used in battery acid cutting.

The formation of assembled batteries may be accomplished using dilute electrolyte which is subsequently dumped and replaced with more concentrated acid for shipment with the battery. This double-fill process allows maximum formation rates, but increases the extent of acid contamination of battery cases. Battery wash requirements are consequently increased as well. As an alternative, batteries may be formed using acid which is sufficiently concentrated to be shipped with the battery after formation has been completed. This single fill battery formation process is widely used in present practice, and is most amenable to wastewater discharge reduction. No significant differences in product characteristics between batteries formed by single fill and double fill techniques are reported.

The formation process generates heat which must be removed from the batteries being formed if an acceptable product quality is to be achieved. The rate at which this heat is generated depends upon the rate at which formation proceeds. When batteries are formed rapidly as is common in present practice, heat generation is so rapid that the batteries must be cooled using fine sprays of water on the battery cases. This contact cooling water constitutes a significant source of wastewater discharge at many plants. When batteries are formed more slowly the heat may be dissipated to the atmosphere without the use of contact cooling water and this source of wastewater discharge is eliminated. In addition, formation at a lower rate reduces gassing during formation and consequently reduces acid mist and fumes associated with this process, limiting the need for scrubbers and the

extent of acid contamination of battery cases and formation areas and equipment.

Battery formation at a lower rate without the use of contact cooling water is practiced by a significant number of manufacturers and was observed in visits to lead subcategory plants. While batteries formed at high rates are frequently placed on conveyors during charging, batteries subjected to low rate formation are often stacked on stationary racks for the formation period which may last up to seven days. Low rate formation requires somewhat more floor area and more charging harnesses than high rate formation to allow for the larger inventory of batteries being formed simultaneously, but eliminates the need for piping and spray nozzles for contact cooling. Battery handling requirements and electric power consumption are substantially identical for high and low rate formation.

Most electrodes used in this subcategory are produced by application of a leady oxide paste to a supporting grid and subsequently curing the pasted electrode. In the curing process, the free lead content of the plates is reduced by oxidation and sulfation resulting in improved paste adhesion and mechanical strength of the electrodes. At most plants, curing is accomplished over several days in curing rooms providing controlled temperature and humidity. No process water is used, and no wastewater results. A few facilities achieve faster plate curing by the use of steam. In this process steam condenses on the electrodes producing a small volume of contaminated process wastewater. This source of wastewater may be eliminated by the use of the more conventional "dry" curing technique. Alternatively, the process wastewater from curing may be reused elsewhere in the process. Possible areas of reuse include acid cutting and paste formulation.

Washing batteries with detergent formulations generates process wastewater which, unlike most lead subcategory waste streams, may not be suitable for reuse in electrolyte preparation or paste formulation. This is due to the presence of detergents and oils and greases removed by detergent action. The provision of a rinse prior to detergent washing allows removal of most of the lead and sulfuric acid from the battery case in a stream which is suitable for reuse in the process. This reduces the loads of these pollutants which must be removed in treatment, and reduces the volume of water needed for detergent washing (due to the reduced amounts of contaminants to be removed from the battery). The volume of wastewater to be treated and discharged is also reduced.

Plant Maintenance and Good Housekeeping – At lead subcategory plants, maintenance and housekeeping practices are of great importance for the implementation of the other in-process control measures which have been previously discussed. Recycle and reuse are especially dependent on the exclusion of contaminants from the process water streams. In

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addition, effective plant maintenance and housekeeping practices may reduce or eliminate some process wastewater sources. Plant maintenance practices such as epoxy coating of racks and equipment which contact process wastewater and containment of the wastewater to minimize such contact reduce the extent of contamination with materials inimical to further use of the water. In addition, these measures minimize corrosion by the acidic wastewater and extend the useful life of production equipment.

Both lead and sulfuric acid are hazardous materials which must be controlled in the work place. At some facilities large quantities of water are used and wastewater discharged in washing down production areas to control workers exposure to these materials. This water use may be substantially reduced or eliminated by the application of plant maintenance and housekeeping practices to reduce spillage and loss of these materials and by the use of dry or water efficient clean-up techniques.

Control of lead dust within the plant also represents a significant water use at some facilities where production floor areas are washed down with hoses or other similarly inefficient techniques. The use of proper material handling techniques to minimize the dust problem, and dry clean-up or water efficient clean-up techniques can reduce or eliminate the volume of discharge from this source. Examples of water efficient clean up techniques include floor wash machines and bucket and mop floor washing.

Equipment maintenance may also contribute significantly to wastewater discharge reduction. At one facility a leaking cooling jacket on a ball mill resulted in contamination of non-contact cooling water with lead creating an additional process wastewater discharge. In addition, leaks in pumps and piping used to handle electrolyte are likely due to the corrosive action of sulfuric acid and may constitute a source of pollutant discharge and necessitate the use of water for washing down affected areas. Proper maintenance of this equipment can minimize discharge from this source.

Leclanche Subcategory

Process water use and wastewater discharge in this subcategory are limited. Many facilities presently report no discharge of process wastewater and most others discharge only limited volumes of wastewater from one or two sources. All of the existing discharges may be eliminated by the implementation of effective in-process control measures, especially wastewater recycle and reuse.

Waste Segregation - At most plants in this subcategory, waste segregation is not required except for the segregation of process wastewater from other waters. Only one or two battery manufacturing

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waste sources are typically encountered in this subcategory, and the characteristics of the resultant waste streams are generally similar. One exception to this observation occurs where paste separators are employed or pasted paper separators are produced. In this case, segregation of wastewater from the paste preparation and handling operations from other process waste streams is important for effective treatment as well as wastewater recycle and reuse.

Wastewater Recycle and Reuse - Essentially all of the process wastewater discharge streams reported in this subcateogry result from washing production equipment, fixtures, and utensils. While the specific recycle and reuse techniques differ, waste streams from both paste preparation and application and from other equipment clean-up may be completely recycled and reused eliminating process wastewater discharged from these sources. Process water used to supply heat for setting paste separators in some cells is also amenable to extensive recycle.

Equipment used in the preparation and application of paste to cells containing paste separators or to paper for use as cell separator material, is generally washed down with water periodically as a part of normal maintenance. The resultant wastewater, generally containing paste, ammonium chloride, zinc and mercury, may be retained and reused in subsequent equipment washing. The build up of contaminants in the wash water can be controlled by using a portion of the wash stream in paste preparation. The contaminants which are normal constituents of the paste are thereby included in the product and discharge of process wastewater pollutants from this operation is eliminated. This recycle and reuse practice is demonstrated at plants which report no process wastewater discharge from paste preparation and application.

Water used in washing equipment and utensils for most other production operations serves primarily to remove insoluble materials such as carbon and manganese dioxide particles. Wastewater from these washing operations can be retained, treated by settling to remove the solids, and reused in further equipment washing. The buildup of dissolved materials in this stream may be controlled by using some of the wash water in electrolyte or cathode formulation. Since the primary source of dissolved salts in the wash water is electrolyte incorporated in cell cathodes or handled in the process equipment, the contaminants in the wash water after settling are normal electrolyte constituents, and no deleterious effect on cell performance will result from this practice.

Water is used to supply heat for setting paste separators by one manufacturer. As a result of contact with machinery used to convey the cells, and occasional spillage from cells, this water becomes moderately contaminated with oil and grease, paste, manganese dioxide particulates, zinc, ammonium chloride and mercury. These

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contaminants, however, do not interfere with the use of this water for heat transfer to the outside of assembled cells. Wastewater discharge from this operation results from manufacturing conveniences, maintenance of the equipment, and from dragout of water on the cells and conveyors. Discharge from each of these process sources may be eliminated by recycle and reuse of the water.

The paste processing steps in making mercury containing separator paper generates a wastewater discharge when the paste mixing equipment is washed. The flow from the wash operation is minimal and can be eliminated either by dry maintenance of the equipment or recycle of the wash water for inclusion in the paste.

Water Use Control and Reduction - Water use in equipment and floor cleaning at some sites in this subcategory may be substantially reduced by the implementation of water use controls or eliminated entirely by the substitution of dry equipment clean-up procedures. Most plants in the subcategory presently employ dry equipment and floor cleaning techniques and discharge no process wastewater. Dry air pollution control devices also serve to reduce water use in this subcategory.

Reduction in water use in cleaning electrolyte handling and delivery equipment and cathode blending equipment may be possible by more effective control of flow rates at several sites in the subcategory. These reductions would decrease the cost of treating wastewater for recycle or of contract removal of the wastes. The potential for such reductions is indicated by the broad range in water use for this purpose within the subcategory. Normalized discharge flows ranging from 0.01 l/kg of cells produced to 6.37 l/kg of cells produced were reported by plants that discharge from this operation. Some of this variation, however, is attributable to variations in the type of cells produced and the nature of the production equipment requiring cleaning. As noted in the previous discussion, this water may be recycled, eliminating all wastewater discharge to the environment from this source. Use of dry maintenance techniques will also serve to eliminate equipment cleaning wastewater discharge. The majority of plants do not report any wastewater discharge from equipment maintenance indicating that these techniques are widely applied in this subcategory.

Water is used in a washing machine at one facility to clean fixtures used to transport cell cathodes to the assembly. Since the machine is often used with only a partial load, wastewater discharge from this process may be reduced by scheduling washing cycles so that a complete load is washed each time. This may require a somewhat increased inventory of the fixtures but will reduce waste treatment costs as well as pollutant discharge.

A majority of manufacturers reported no wastewater discharged from floor wash procedures and it is concluded that dry maintenance techniques are widely applied in the subcategory although not specifically identified by most facilities. Some of these dry techniques include either sweeping or vacuuming floor areas and using desiccant materials in instances of spillage.

Process Modification - Variations in manufacturing processes and products in this subcategory are observed to correspond to variations in process water use and wastewater discharge. Significant differences in wastewater discharge are observed between plants producing cells with paste separators and pasted paper separators. Among plants producing cells with paste separators differences in wastewater discharge result from differences in assembly technique and in the paste formulation employed. Relatively high water use and wastewater discharge are also associated with the manufacture of foliar batteries. While cells using pasted paper and paste separators serve the same applications and are directly competitive, the foliar batteries are designed for a unique application.

The manufacture of cells using heat-set paste separators is observed to produce a wastewater discharge from the paste setting operation. This source of discharge may be eliminated by substitution of a paste formulation which sets at a lower temperature or by use of pasted paper separators. Industry personnel report that production of paste separator cells is significantly less costly than the manufacture of cells with pasted paper separators.

Plant Maintenance and Good Housekeeping - Dry clean-up of production areas is practiced at essentially all sites in this subcategory. In addition, most facilities employ dry cleaning techniques in maintaining process equipment. These practices contribute to the low wastewater discharge rates typical of this subcategory.

Lithium Subcategory

Process water use and wastewater discharges in the lithium subcategory are limited. The cell anode material reacts vigorously with water necessitating the use of non-aqueous electrolytes and dry processes for most manufacturing operations. Correspondingly, opportunities for in-process control are also limited.

Thermal batteries similar to those produced in the calcium subcategory are manufactured in this subcategory including the production of heat generation component material. As discussed for the calcium subcategory, this waste stream may be recycled after settling eliminating this source of wastewater discharge.

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At some plants in this subcategory, wet scrubbers are used to control emissions from sulfur dioxide and thionyl chloride depolarizer materials. Extensive recycle of the scrubber discharge streams is possible, reducing the volume of wastewater discharge to minimal values.

Magnesium Subcategory

Half of the plants in this subcategory report zero discharge of magnesium battery manufacturing process wastewater. The remaining facilities report process wastewater discharges from eight process operations to which a variety of in-process control techniques may be applied.

At one plant which produces magnesium anode thermal batteries, process wastewater discharges result from wet scrubbers on dehumidification equipment used to control conditions in process areas and from the production of heating component material. These waste streams may be extensively recycled significantly reducing or eliminating wastewater discharges from these sources.

Significant wastewater discharge from floor washing operations is also reported in this subcategory and may be reduced by the use of water-efficient or dry floor cleaning techniques. Alternatively, the floor wash water may be treated and recycled.

Zinc Subcategory

Manufacturing operations in the zinc subcategory involve a wide variety of process water uses and wastewater discharge sources. Wastewater discharges result from active material preparation, electrode processing and associated rinses, cell washing, and equipment and area cleaning. A variety of techniques may be applied within the process to reduce the volume of wastewater or mass of pollutants discharged.

Waste Segregation - The segregation of individual process waste streams which differ markedly in character is an important factor in effective water pollution control. The segregation of non-contact cooling and heating water from process wastes is essential for effective removal of process pollutants in end-of-pipe treatment. Waste segregation is presently practiced at most plants in the subcategory, many of which recirculate non-contact cooling water through cooling towers.

Many cell cleaning or electrode preparation operations involve the use of organic reagents such as methanol, methylene chloride, and hydrazine which ultimately leave the process in organic laden wast streams. The segregation of the organic laden waste streams

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waste streams bearing predominantly toxic metals and suspended solids is necessary if these pollutants are to be removed effectively and without incurring excessive costs.

The volume of the organic laden waste streams is quite small at most sites and contract removal to a central location is generally less costly and is predominant in present practice. Efficient segregation therefore also contributes to minimizing the cost of contract disposal.

Silver oxides are used as the depolarizer in some of the cells manufactured in this subcategory and silver is present at particularly high concentrations in wastewater streams from some active material and cathode preparation operations. The segregation of these waste streams may allow economic recovery of the silver for use on site or return to a refinery.

Amalgamation of zinc anodes consumes large quantities of mercury, part of which enters process wastewater. Specific process waste streams contain substantial concentrations of mercury and segregation and separate treatment of these streams can reduce the total amount of mercury released to the environment.

Wastewater Recycle and Reuse - Process operations in this subcategory produce waste streams which may be recycled for use in the same operation or reused at some other point in the process. Waste streams which may be recycled or reused in this subcategory include a variety of process solutions, cell wash and rinse wastewater, electrolyte dripped in battery filling, equipment and area wash water, and wastewater from rinsing amalgamated zinc powder. While most of these streams may be recycled without treatment, a few, notably the floor and equipment wash wastewater, may require treatment before being recycled.

The opportunity for wastewater recycle and reuse in this subcategory is in general minimal because plants in the subcategory do not employ wet scrubbers and the electrolyte content of many zinc subcategory cells is low. Process solutions in this subcategory are commonly reused extensively until either depleted or heavily contaminated, and consequently represent a minimal contribution to the total wastewater flow. Reuse of process solutions significantly reduces pollutant loads discharged to waste treatment, and also yields economic benefits in reduced consumption of process chemicals.

At several facilities it was observed that the addition of electrolyte to assembled cells resulted in small volumes of dripped or spilled electrolyte which was collected and discarded. With care in maintaining the cleanliness of the drip collection vessels, this

electrolyte can be returned for addition to cells eliminating this source of highly concentrated wastes.

For cell washing the observation was made that water use was governed by the need to ensure adequate contact of the wash solution and rinse water with the complete cell surface. Recycle of cell wash water and solutions is therefore feasible. Cell wash operations in which recycle is practiced have substantially lower discharge volumes than similar cell washes without recycle.

Water is frequently used to wash production equipment, especially equipment used in mixing slurries for the preparation of pasted electrodes and for the amalgamation of zinc powder. The usual purpose of this equipment wash water is to remove solids from the equipment. Because the concentrations of dissolved materials in the equipment wash water are generally moderate, the wastewater from equipment washing can be recycled for further use with any minor treatment. This practice is employed so effectively at one plant that water from equipment washing is discharged only once every six months.

Water used in washing production floor areas also serves primarily to remove solid materials. Wastewater from this operation may be recycled generally if suspended solids removal is provided; where mercury is used in the production areas being cleaned, the wastewater must be treated by a technique which is effective in removing mercury.

Wastewater from rinsing wet amalgamated zinc powder contains zinc, mercury, and soluble materials used in the amalgamation process. Countercurrent rinsing, if applied to these rinse steps, will result in smaller volume discharge which contain relatively high concentrations of mercury and zinc. These contaminants may readily be reduced to levels acceptable for reuse of the water in washing floors.

Water Use Control and Reduction - The degree of control of process water use is observed to vary significantly among zinc subcategory plants. Production normalized process water use and wastewater discharge in specific process operations are observed to vary by as much as a factor of twenty between different plants, and by factors of six or more from day to day at a single plant. The most significant area where wastewater discharge may be reduced through more effective flow control and efficient water use is in rinsing active materials, electrodes and finished cells. These reductions may often be achieved by very simple actions such as turning off rinse water flows when production stops, by adjusting rinse flow rates to correspond to varying levels of production activity, and by the modification of rinsing techniques to provide multistage countercurrent rinses.

Other techniques which reduce process flows include the replacement of wet processes with processes that do not use water. For example,

floor maintenance can be performed by using dry sweeping or vacuuming techniques. In instances of spillage, desiccant material can be applied with subsequent dry floor cleaning. Since most plants report no wastewater from cleaning, these dry techniques are apparently widely applied in the subcategory although not specifically identified by most facilities. Only a few facilities discharge significant volumes of floor wash water due to such practices as hosing down floor areas.

Material recovery may also significantly reduce pollutant loadings. Zinc cell manufacturers practice material recovery for silver and mercury from both process wastewater and reject cells.

Process Modification - Manufacturing processes in this subcategory are widely varied often corresponding to differences in product types, physical configuration and performance characteristics. A significant number of manufacturing operations are governed by military specifications. Some of the observed variations, however, do not correspond to discernible differences in the end product, and reflect only differences in plant practices.

Zinc powder for use in anodes is amalgamated by three techniques; "wet" amalgamation in which the zinc powder and mercury are mixed in an aqueous solution and subsequently rinsed, drained off and discharged; "gelled" amalgamation in which the zinc and mercury are moistened with a small volume of electrolyte and mixed with binders to produce an amalgamated anode gel; and "dry" amalgamation in which mercury and zinc are mixed without the introduction of any aqueous phase. Since amalgamated material produced by all three techniques is used on a competitive basis in many cell types, the substitution of a dry amalgamation technique for wet amalgamation may be considered a viable in-process control technique for the reduction of process wastewater discharges in this subcategory.

Silver peroxide is presently produced by several chemical processes at facilities in this subcategory, and different wastewater discharge volumes are observed to result. Substantially less wastewater per unit of product is discharged from one process and the process solutions are completely recycled.

Cell wash procedures and materials are highly variable in this subcategory, and the resultant normalized discharge volumes vary over nearly three orders of magnitude, from 0.09 to 34.1 1/kg of cells produced. At some sites, organic solvents are used to remove oils and greases from cell cases eliminating most water use. At others cells are simply rinsed with water without the use of any chemicals in the cell wash.

Cell wash formulations used sometimes contain toxic pollutants, especially chromium and cyanide, not otherwise encountered in battery manufacturing wastewater. Cells are successfully washed at many facilities using formulations which do not contain cyanide or chromate. Therefore substitution of an alternative chemical in the cell wash is a practical method for eliminating these pollutants from wastewater discharges in this subcategory.

<u>Plant Maintenance and Good Housekeeping</u> - As in subcategories previously discussed, plant maintenance and housekeeping practices play a vital role in water pollution control. Because large quantities of mercury are used in this subcategory, good housekeeping practices to control losses of the toxic metal are of particular importance for both water pollution control and industrial hygiene. These include the maintenance of floors in process areas where mercury is used, to eliminate cracks and pits in which mercury could be trapped necessitating excessive water use in cleaning. Most plant maintenance and housekeeping practices applicable in this subcategory are similar to those previously discussed for other subcategories.
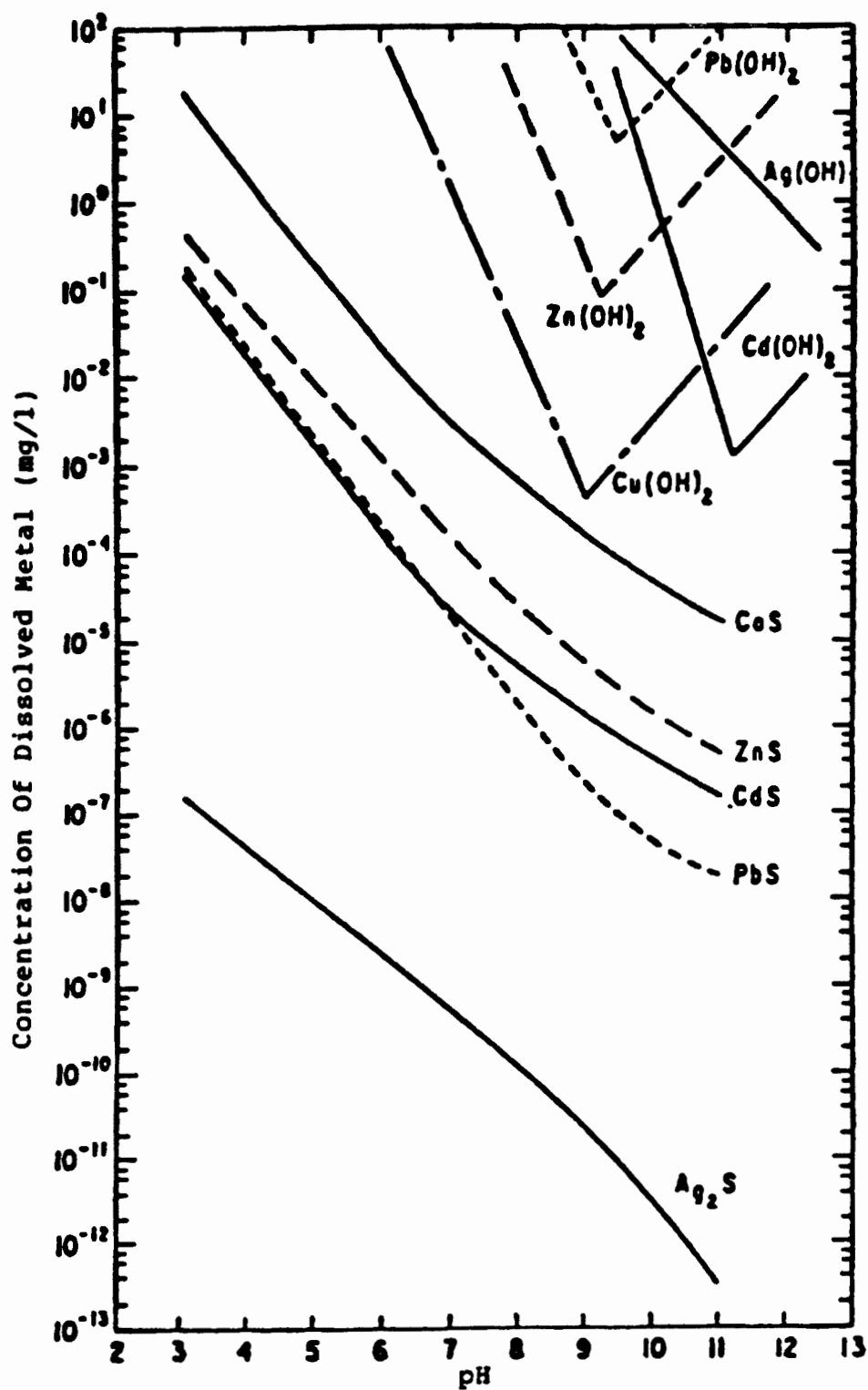
FIGURE VII-1

COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES AND SULFIDE AS A FUNCTION OF pH

571
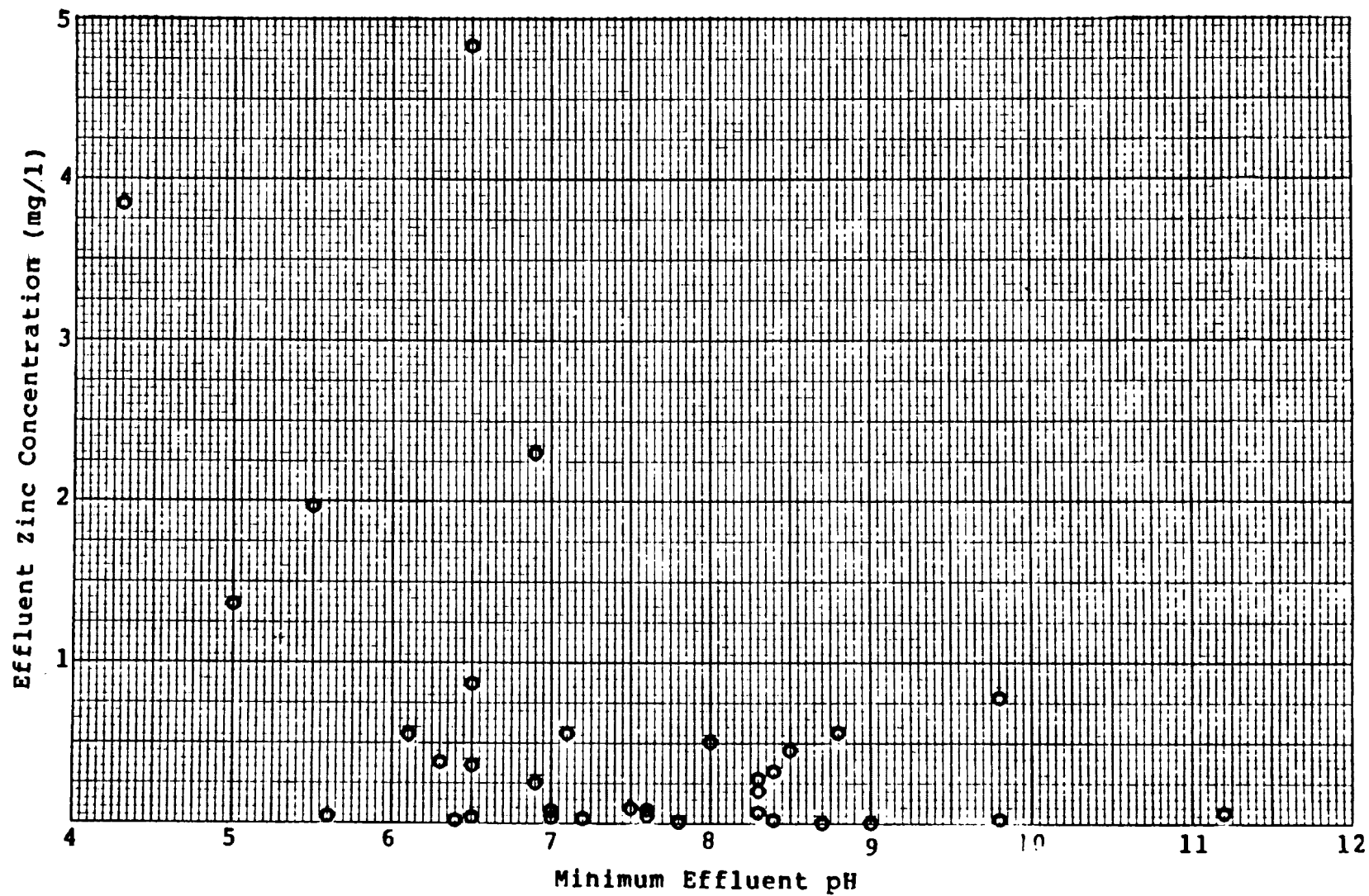
FIGURE VII-2

EFFLUENT ZINC CONCENTRATION vs. MINIMUM EFFLUENT pH
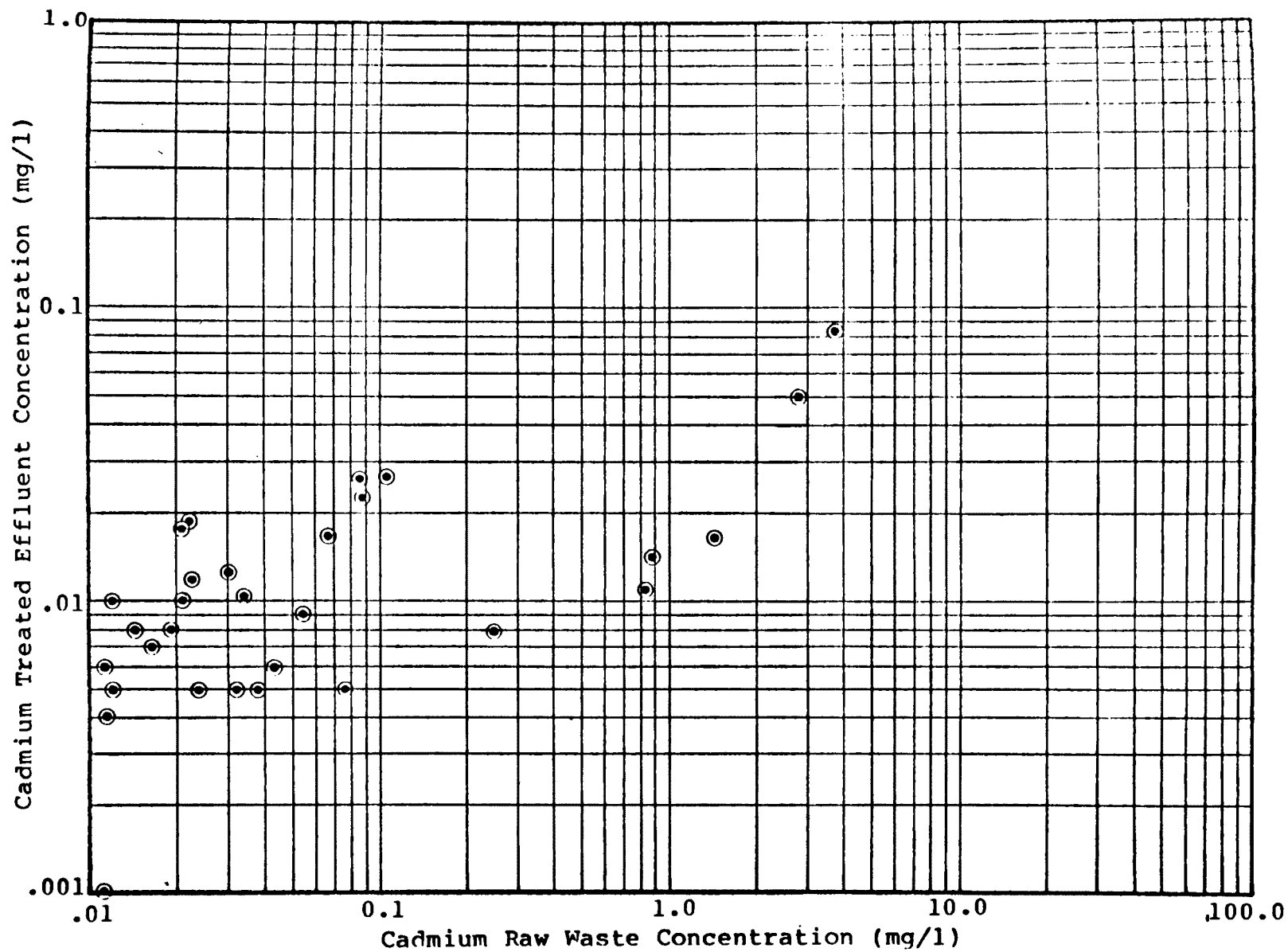
(Number of observations = 38)

FIGURE VII-3

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
CADMIUM
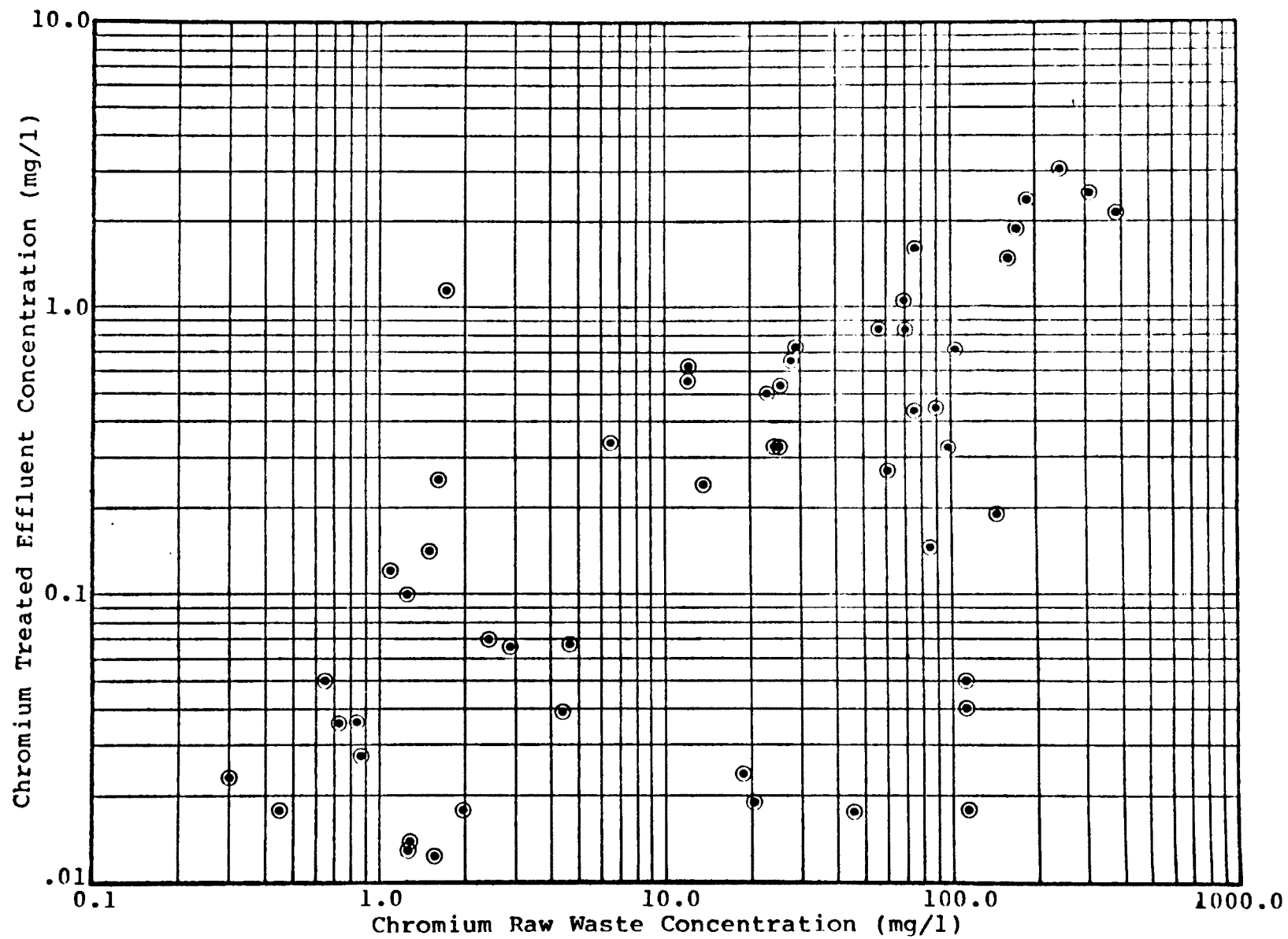
(Number of observations = 64)

FIGURE VII-4

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
CHROMIUM
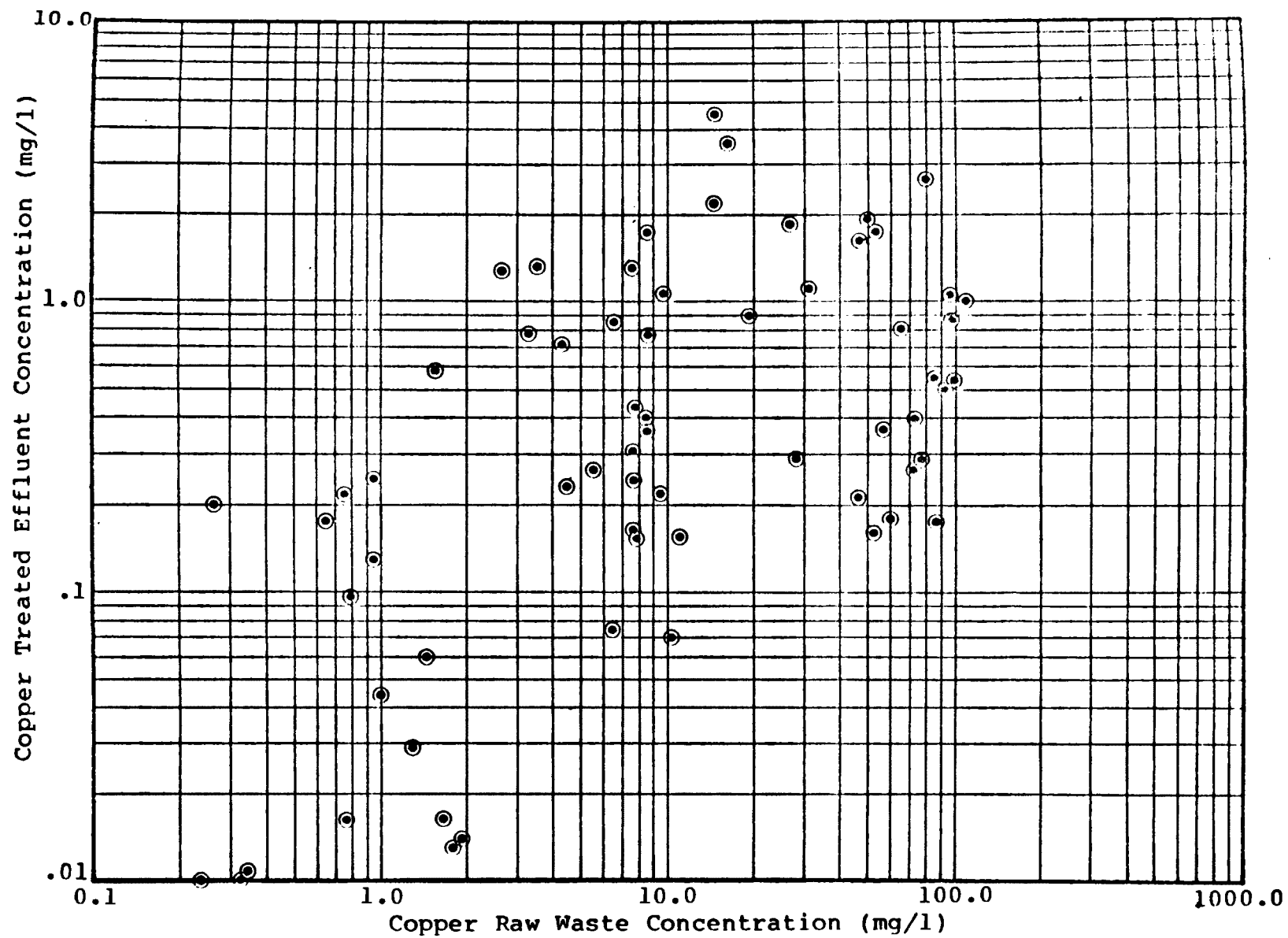
(Number of observations = 74)

FIGURE VII-5

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
COPPER

Iron Treated Effluent Concentration (mg/l)

10.0

1.0

0.1

0.01

0.1　　　　　　　　　1.0　　　　　　　　　10.0　　　　　　　　　100.

Iron Raw Waste Concentration (mg/l)
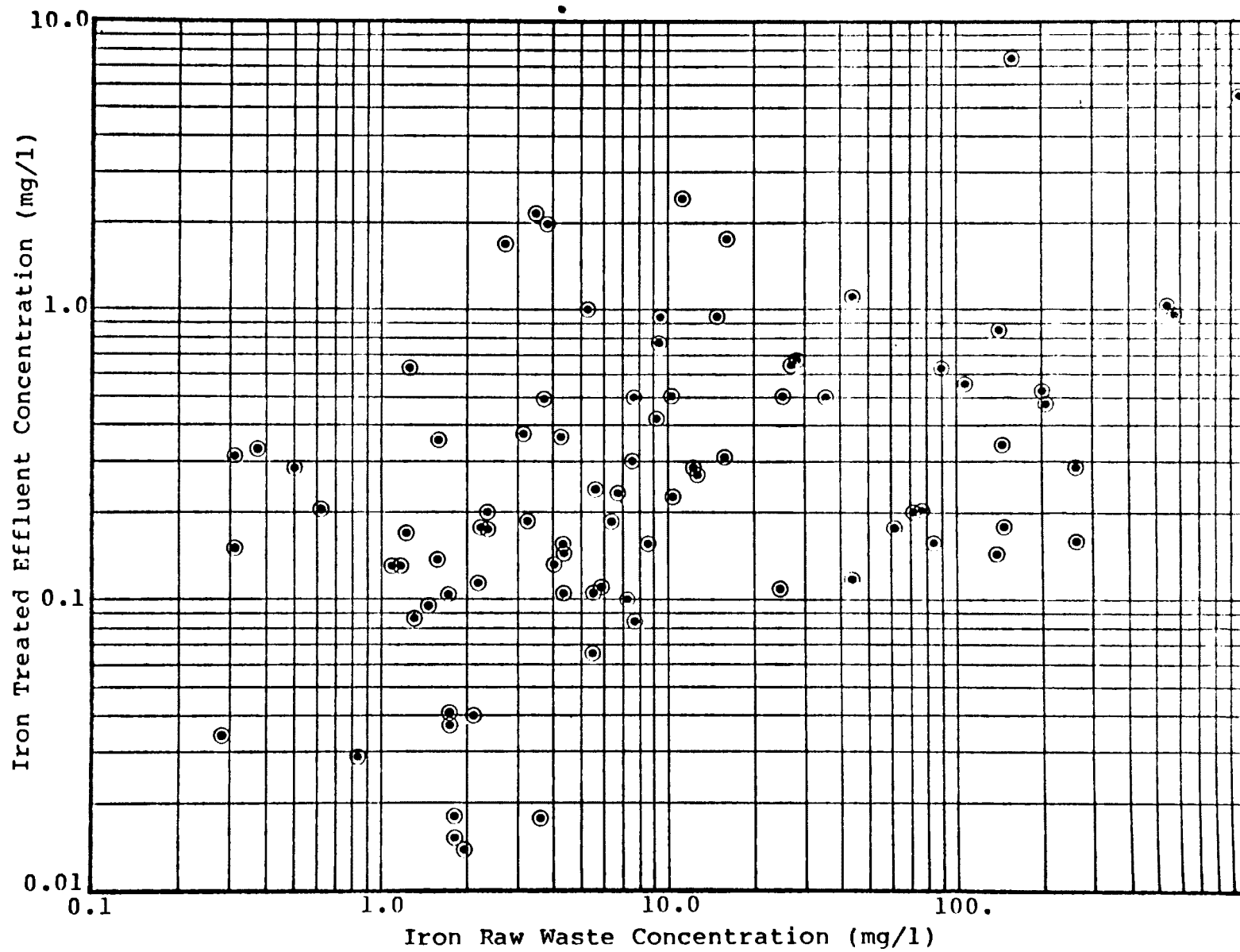
(Number of observations = 88)

FIGURE VII-6

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
IRON

Lead Treated Effluent Concentration (mg/l)

Lead Raw Waste Concentration (mg/l)
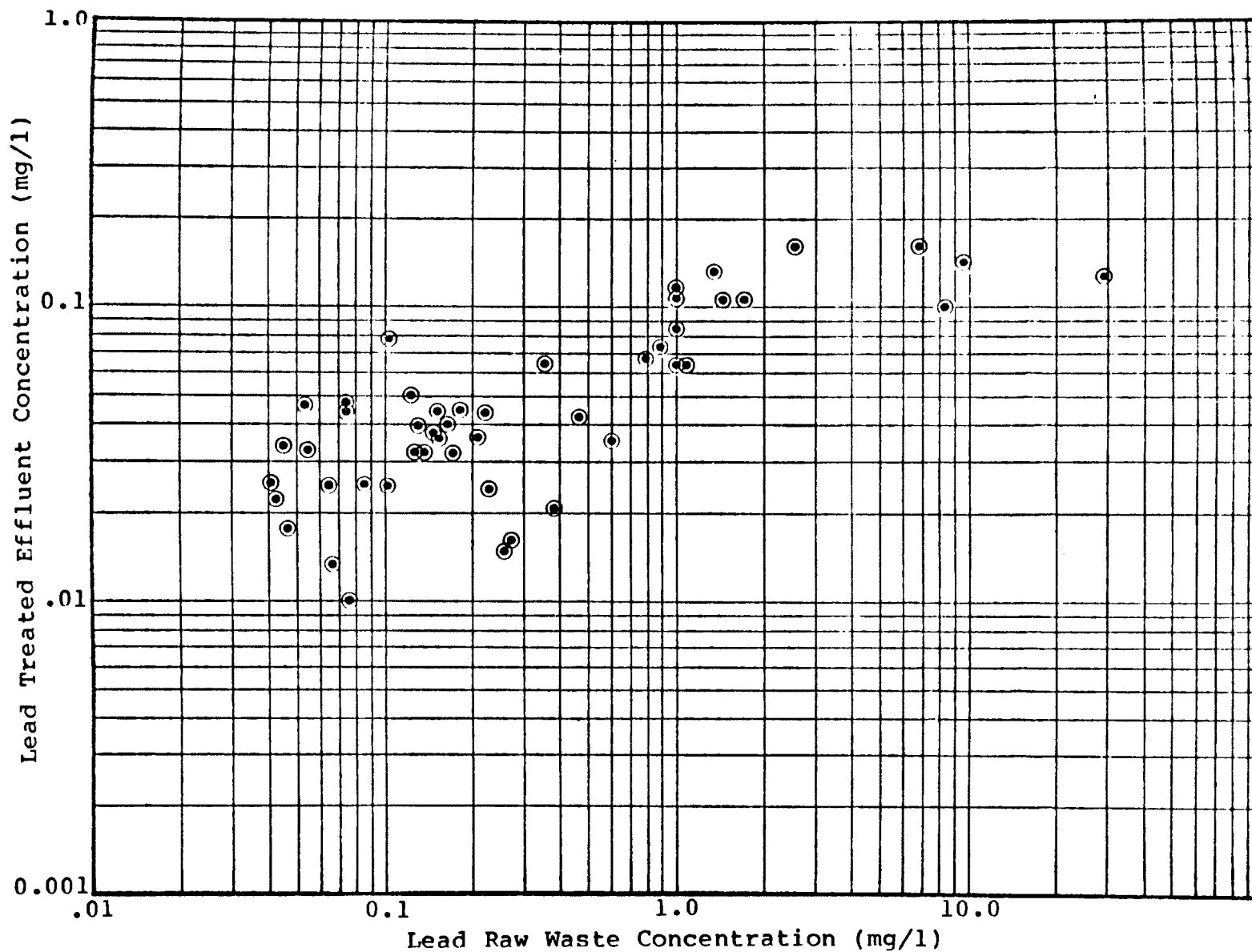
(Number of observations = 85)

FIGURE VII-7

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
LEAD

577
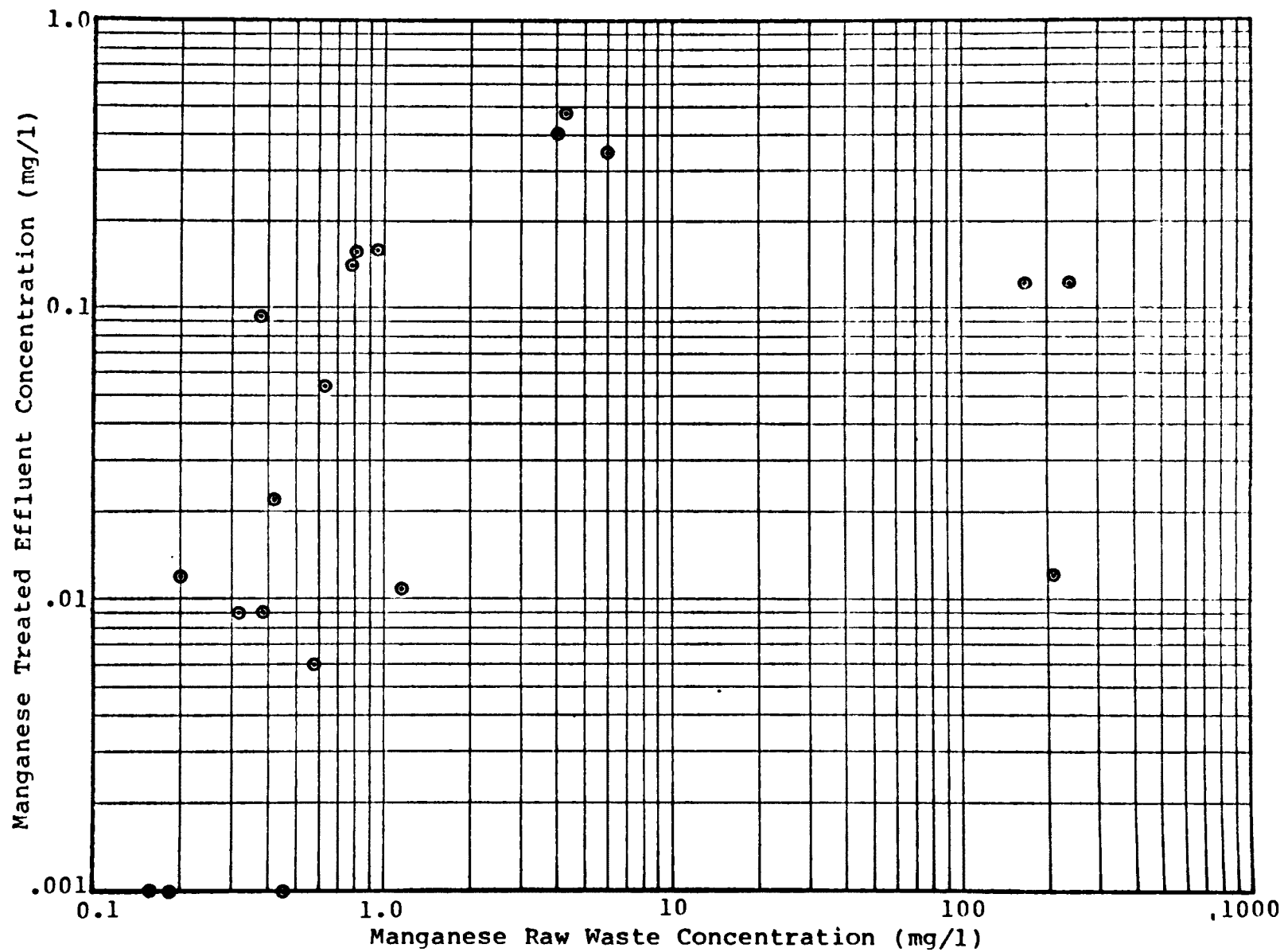
FIGURE VII-8

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
MANGANESE

(Number of observations = 20)

578

579
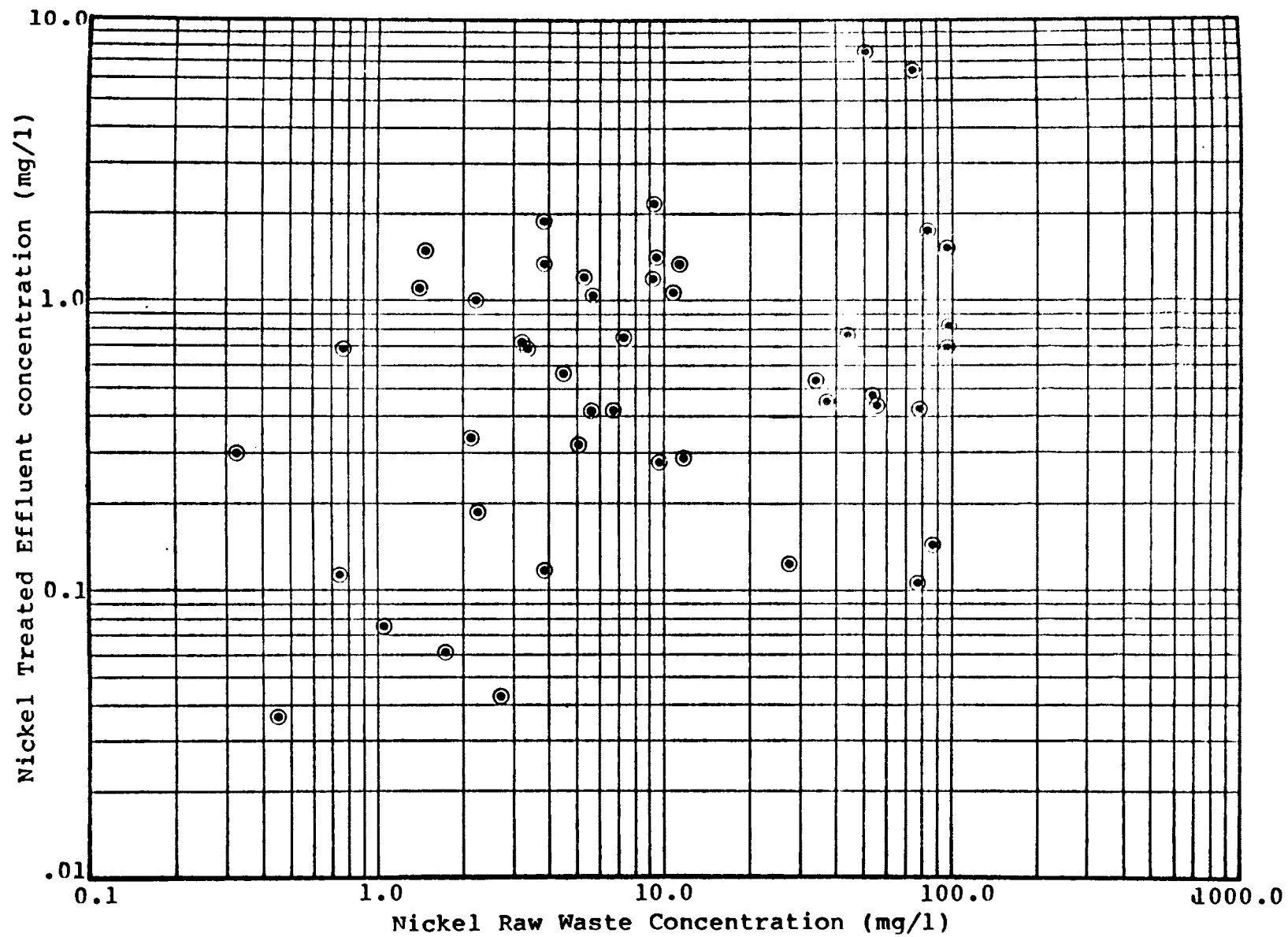
(Number of observations = 61)

FIGURE VII-9

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
NICKEL
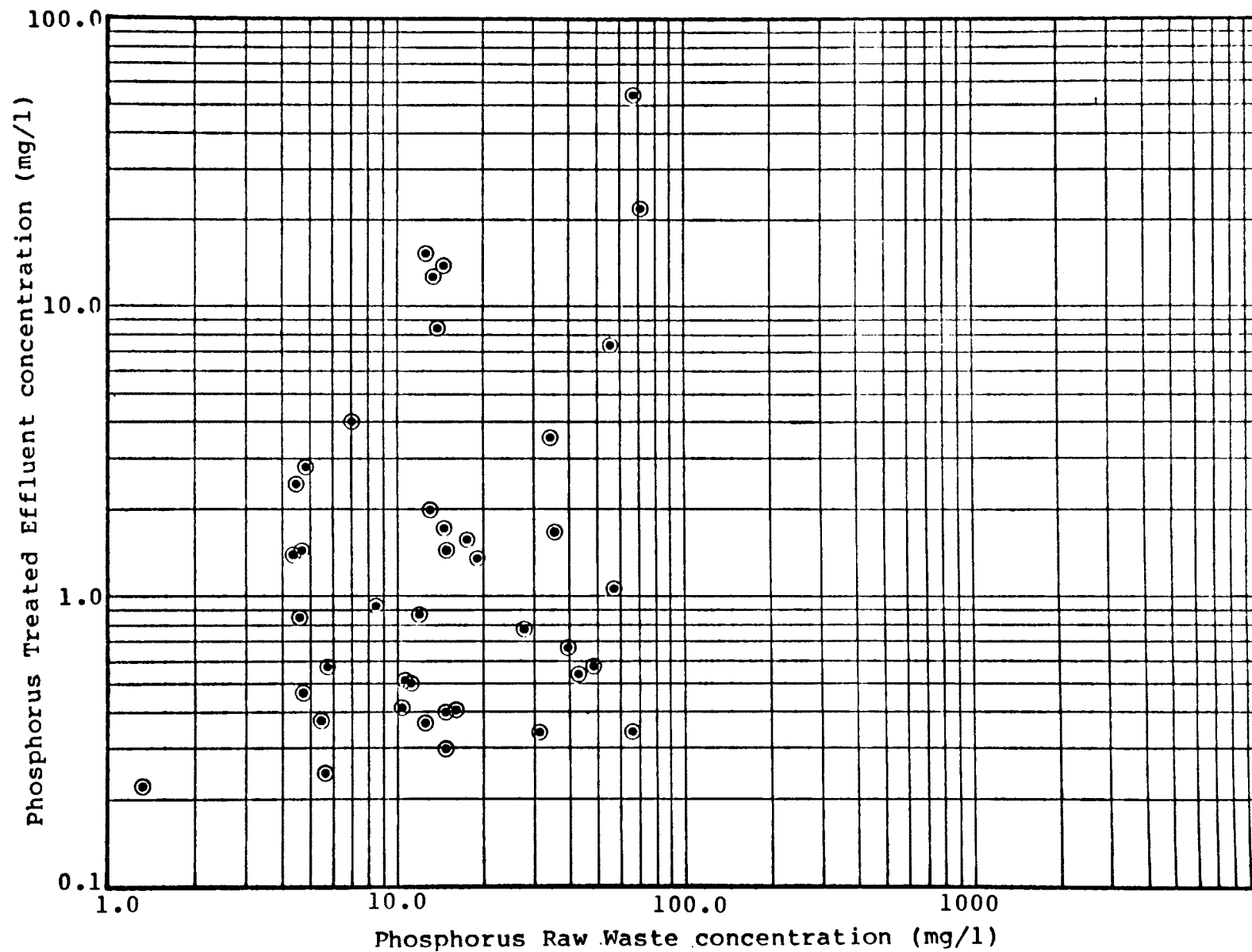
(Number of observations = 44)

FIGURE VII-10

HYDROXIDE PRECIPITATION & SEDIMENTATION EFFECTIVENESS
PHOSPHORUS

(Number of observations = 69)

FIGURE VII-11

HYDROXIDE PRECIPITAITON & SEDIMENTATION EFFECTIVENESS
ZINC
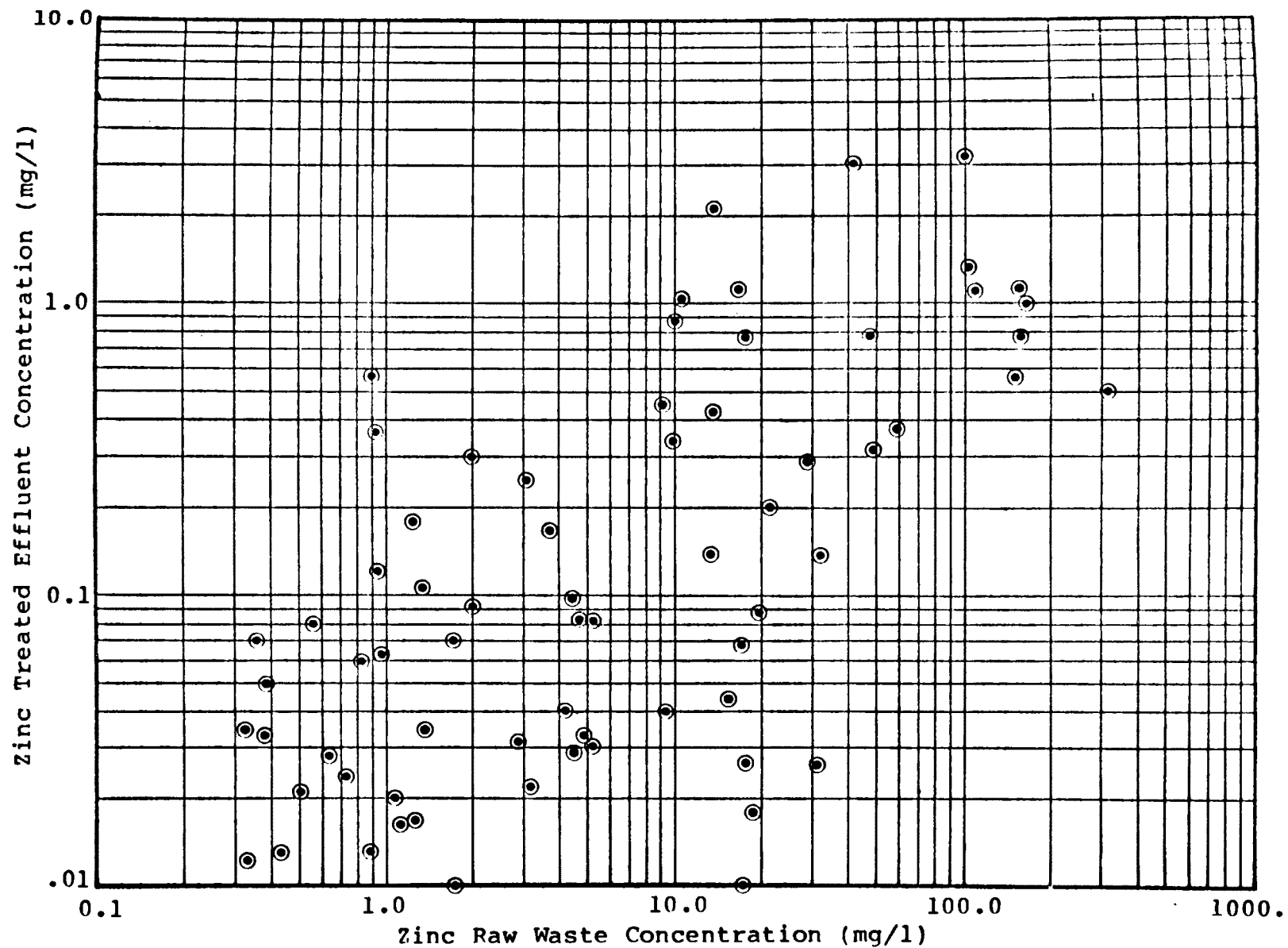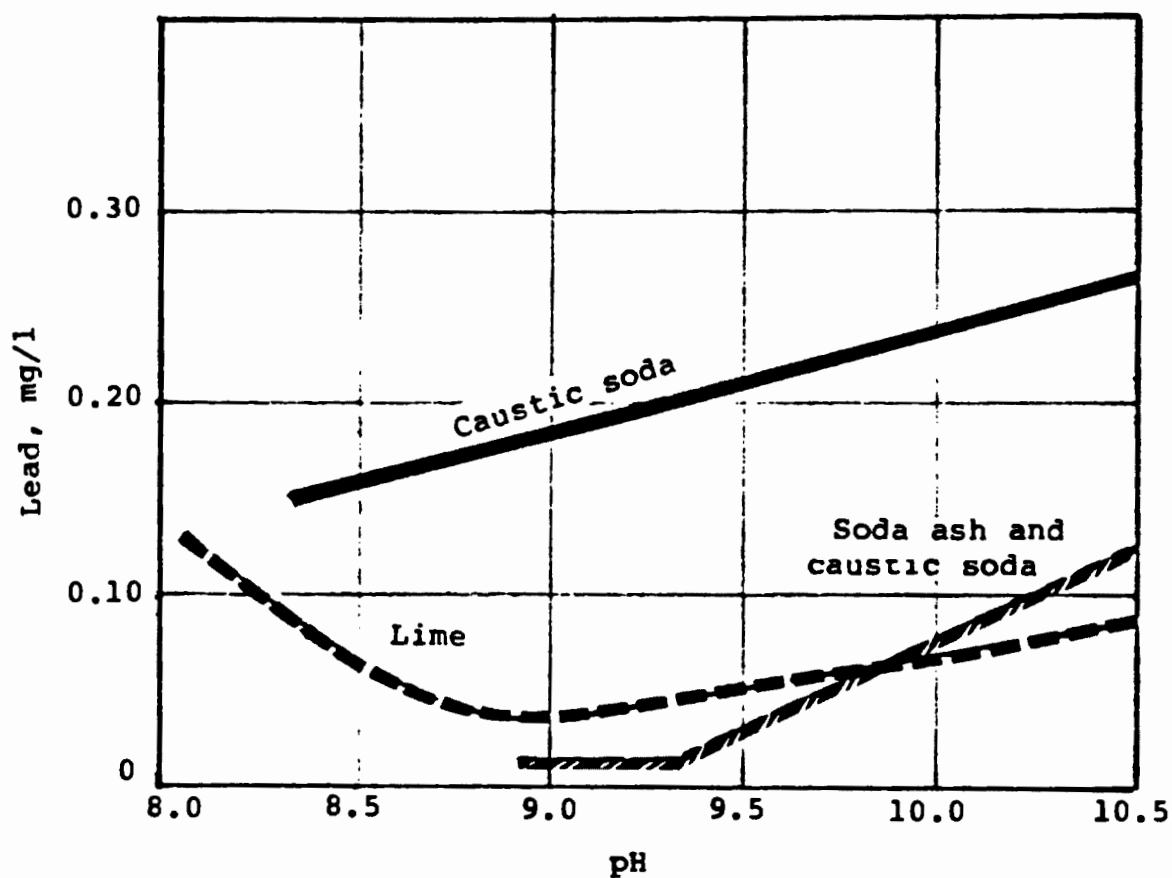
FIGURE VII-12
LEAD SOLUBILITY IN THREE ALKALIES

582

Sedimentation Basin
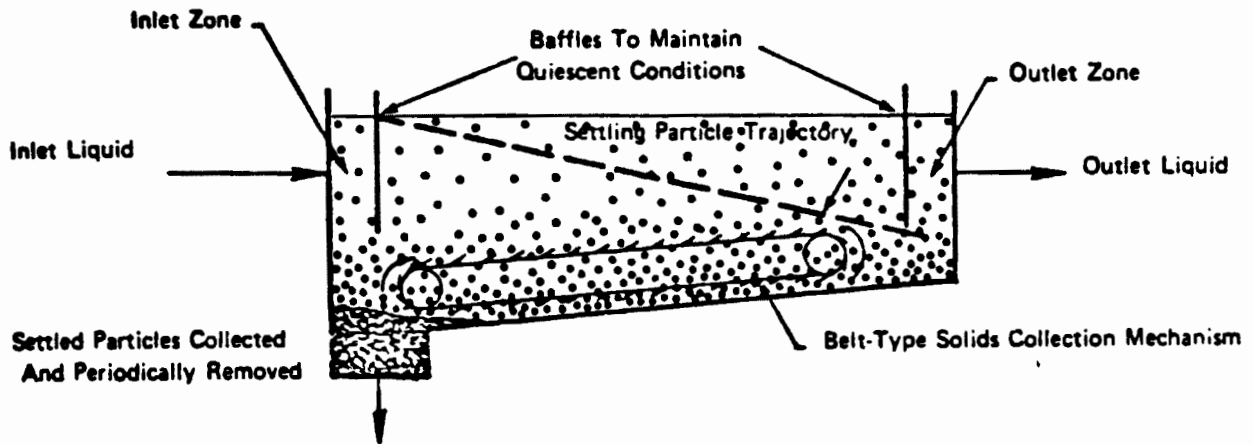
Circular Clarifier
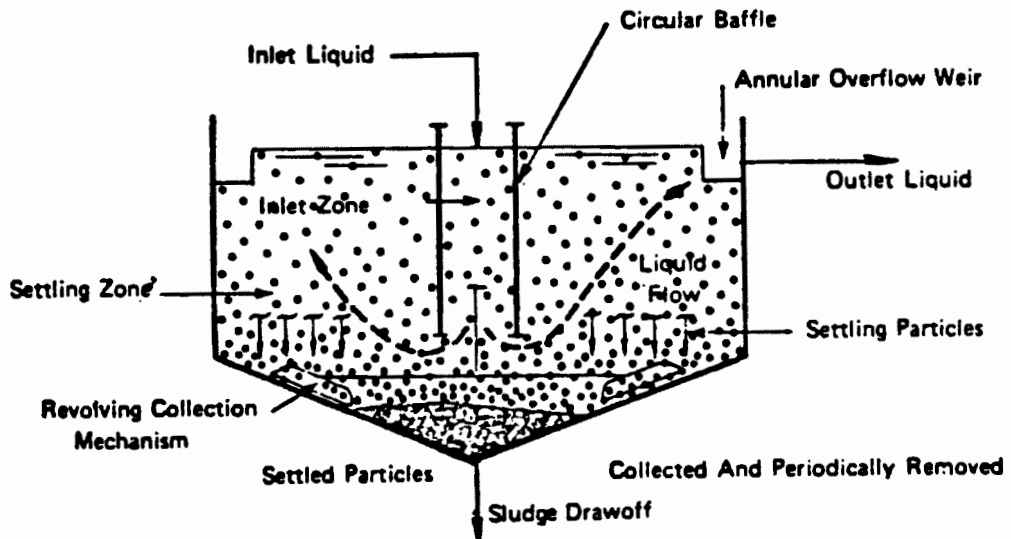
FIGURE VII-13

REPRESENTATIVE TYPES OF SEDIMENTATION

583
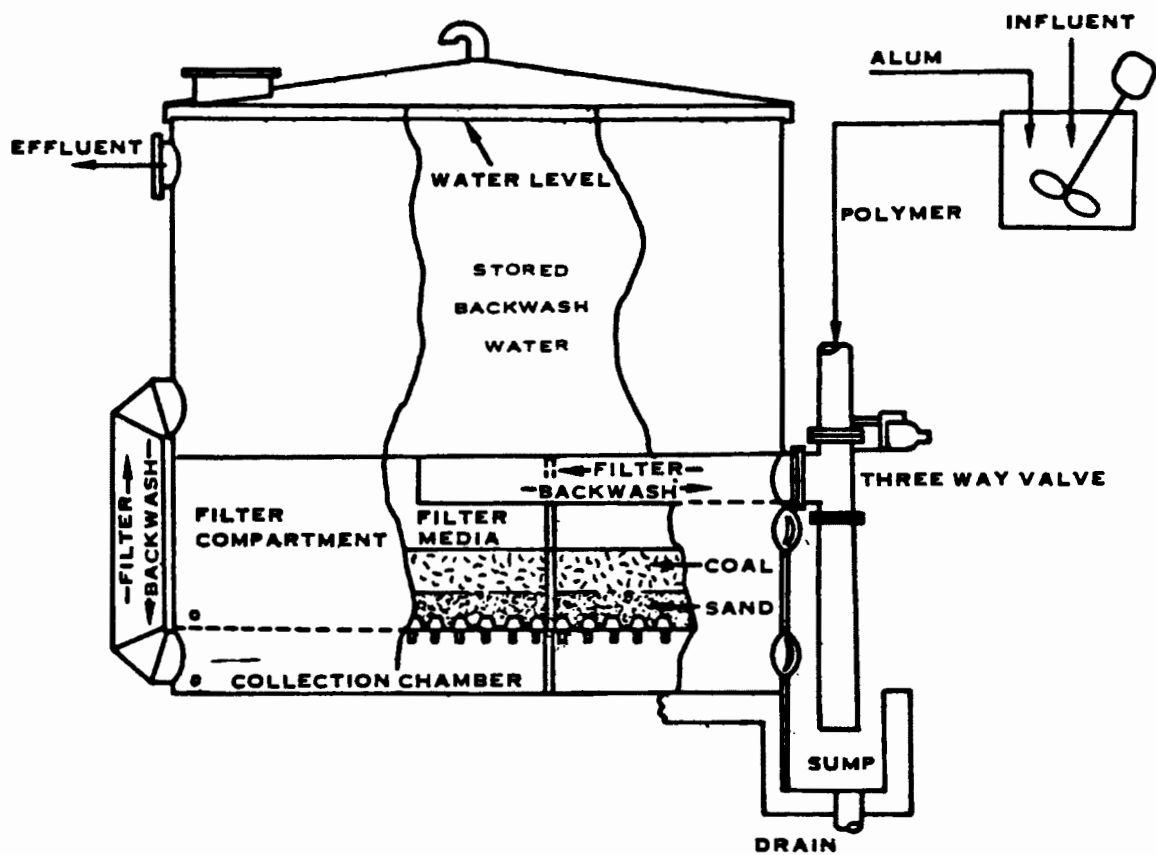
FIGURE VII-14

GRANULAR BED FILTRATION

584
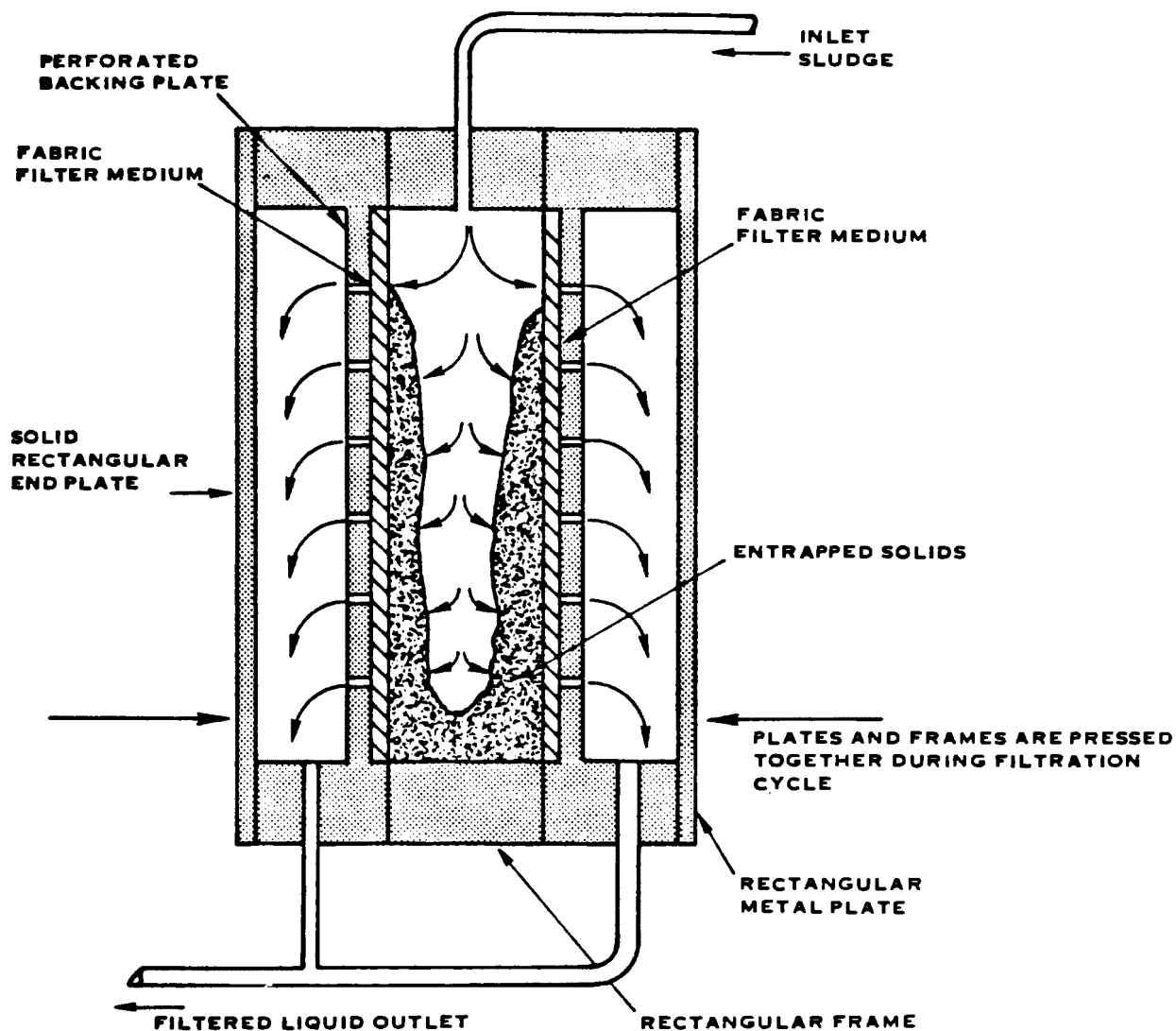
FIGURE VII-15

PRESSURE FILTRATION

585

FABRIC OR WIRE
FILTER MEDIA
STRETCHED OVER
REVOLVING DRUM

DIRECTION OF ROTATION

ROLLER

TRUNNION

VACUUM
SOURCE

SOLIDS SCRAPED
OFF FILTER MEDIA

STEEL
CYLINDRICAL
FRAME

LIQUID FORCE
THROUGH
MEDIA BY
MEANS OF
VACUUM

INLET LIQUID
TO BE
FILTERED

SOLIDS COLLECTION
HOPPER

TROUGH

FILTERED LIQUID
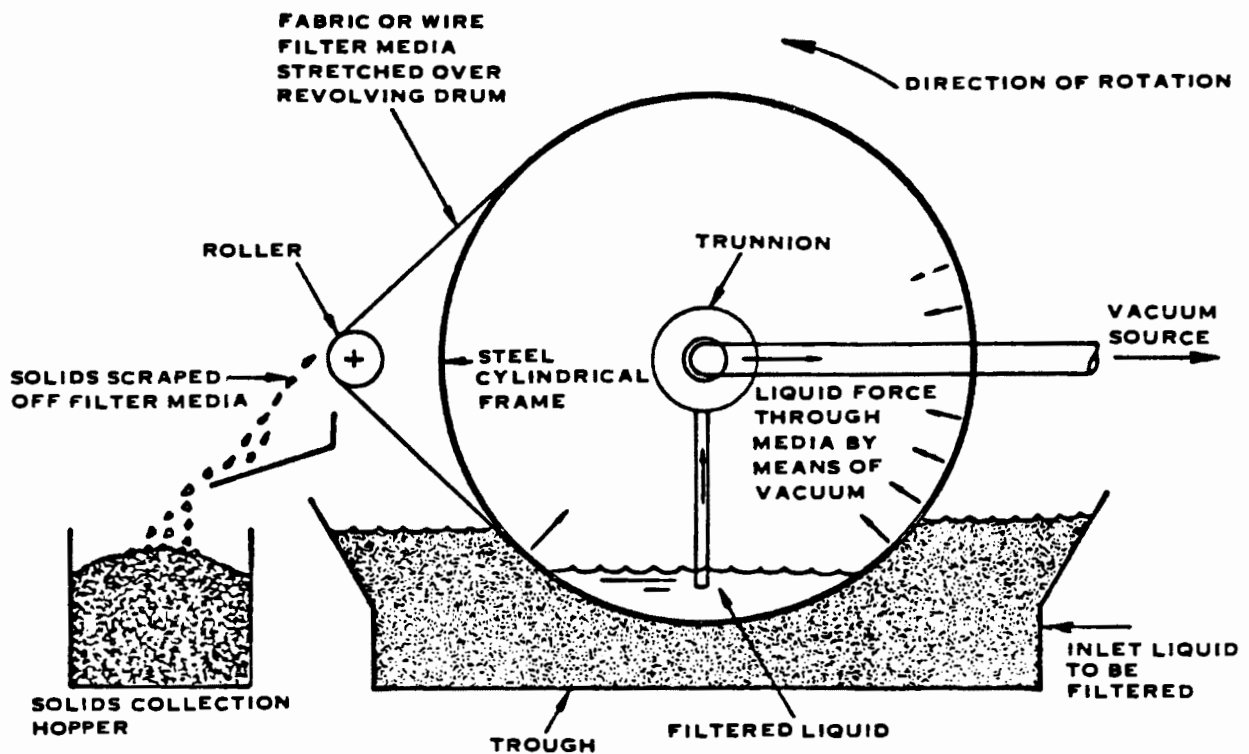
FIGURE VII-16

VACUUM FILTRATION

586

FIGURE VII-17

CENTRIFUGATION

587

RAKE ARM

BLADE

COUNTERFLOW
INFLUENT WELL

CONDUIT
TO MOTOR

INFLUENT

WALKWAY

DRIVE UNIT

CONDUIT TO
OVERLOAD
ALARM

OVERLOAD ALARM

EFFLUENT WEIR

EFFLUENT PIPE

DIRECTION OF ROTATION

EFFLUENT CHANNEL

PLAN

TURNTABLE
BASE

HANDRAIL

DRIVE

WEIR

WATER LEVEL

CENTER COLUMN

INFLUENT

FEED WELL

CENTER CAGE

STILTS

SQUEEGEE

CENTER SCRAPER

SLUDGE PIPE

FIGURE VII-18

GRAVITY THICKENING

588

PLAN

- 6-IN. FINE SAND
- 3-IN. COARSE-SAND
- 3-IN. FINE GRAVEL
- 3-IN. MEDIUM GRAVEL
- 3 TO 6 IN. COARSE GRAVEL

6-IN. CI PIPE

PIPE COLUMN FOR GLASS-OVER

3-IN. MEDIUM GRAVEL

2-IN. COARSE SAND

6-IN. UNDERDRAIN LAID WITH OPEN JOINTS

SPLASH BOX

6-IN VITRIFIED PIPE LAID WITH PLASTIC JOINTS

6-IN. VITRIFIED PIPE LAID WITH OPEN JOINTS

6-IN. FLANGED SHEAR GATE

2-IN. PLANK WALK

SECTION A-A
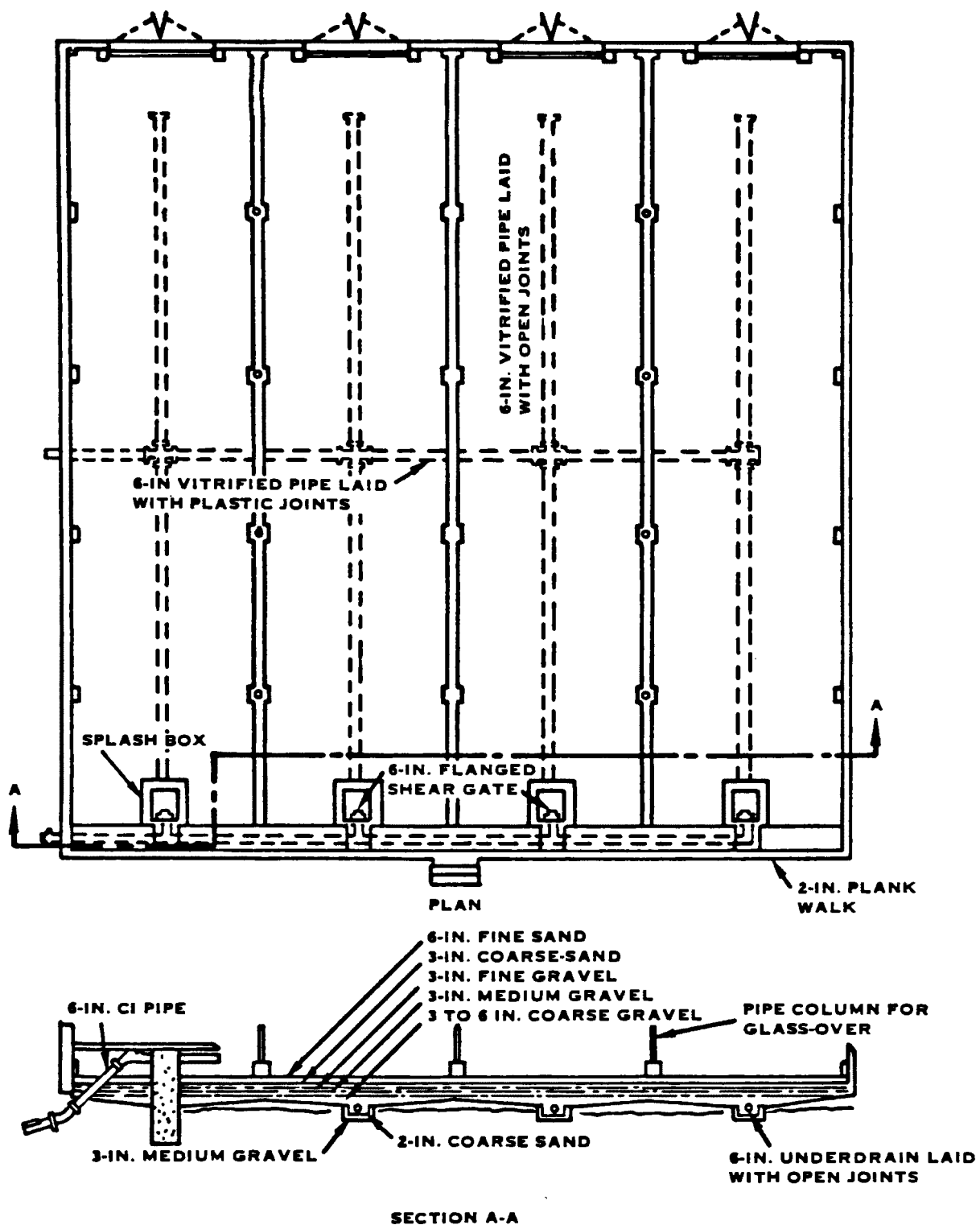
FIGURE VII-19

SLUDGE DRYING BED

589

EXHAUST

WATER VAPOR — FAN

PACKED TOWER
EVAPORATOR

HEAT
EXCHANGER

STEAM

STEAM
CONDENSATE

CONCENTRATE

AIR

WASTEWATER — PUMP

ATMOSPHERIC EVAPORATOR

EVAPORATOR   VAPOR-LIQUID
MIXTURE   SEPARATOR   CONDENSER

WATER VAPOR

STEAM

COOLING
WATER

STEAM
CONDENSATE

WASTEWATER

LIQUID RETURN

CONDENSATE

VACUUM PUMP

CONCENTRATE

CLIMBING FILM EVAPORATOR

590

VACUUM LINE   VACUUM
PUMP

COOLING
WATER

CONDENSATE

WASTEWATER

STEAM

CONCENTRATE

STEAM
CONDENSATE

SUBMERGED TUBE EVAPORATOR

VAPOR

HOT VAPOR   CONDENSER   COOLING
WATER

CONDENSATE

VACUUM PUMP

STEAM

STEAM
CONDENSATE

CONDENSATE

EXHAUST

ACCUMULATOR

WASTE
WATER
FEED

CONCENTRATE

CONDENSATE
FOR
REUSE

CONCENTRATE FOR REUSE

DOUBLE-EFFECT EVAPORATOR

FIGURE VII-20

TYPES OF EVAPORATION EQUIPMENT
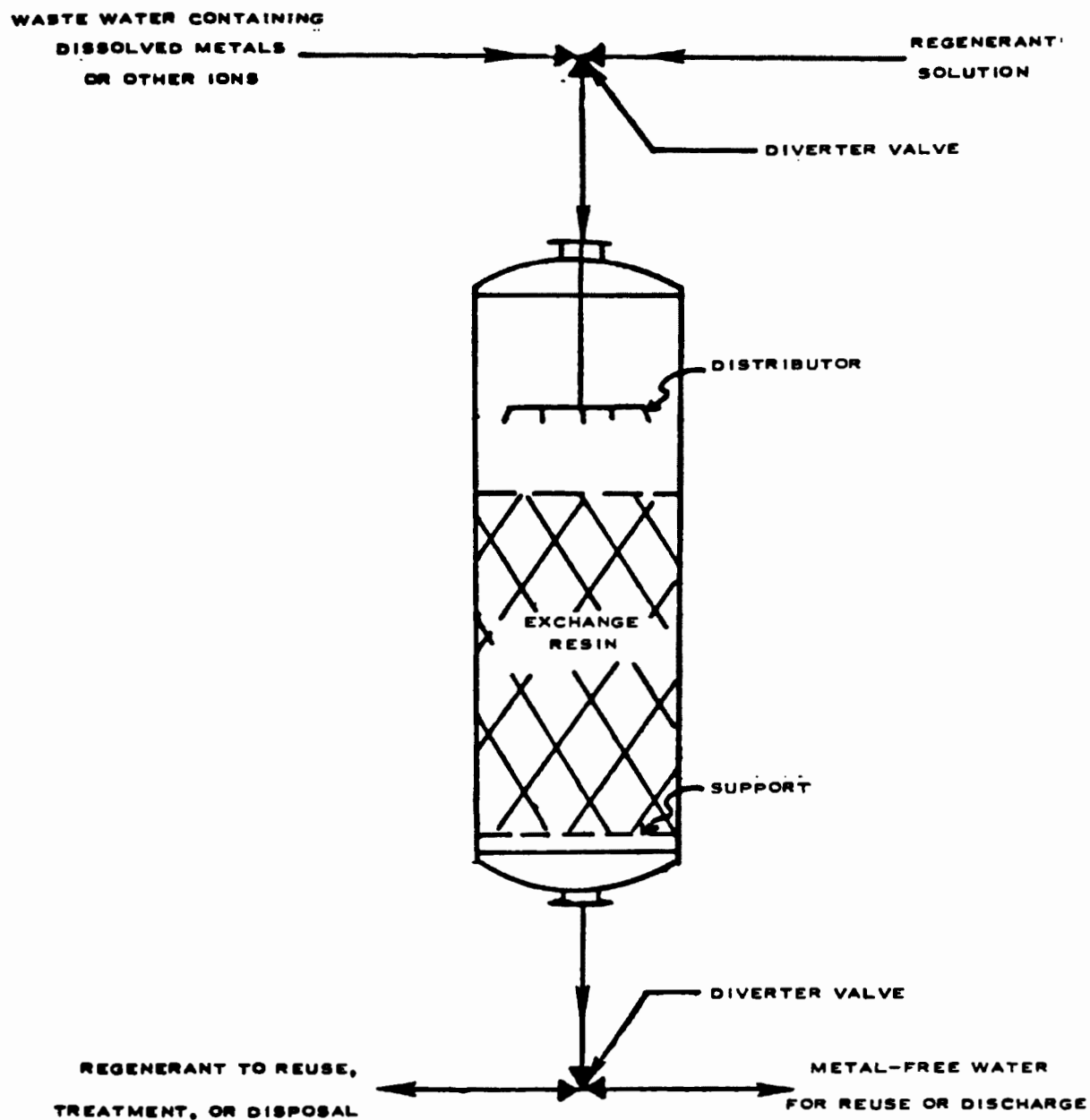
FIGURE VII-21

ION EXCHANGE WITH REGENERATION

591
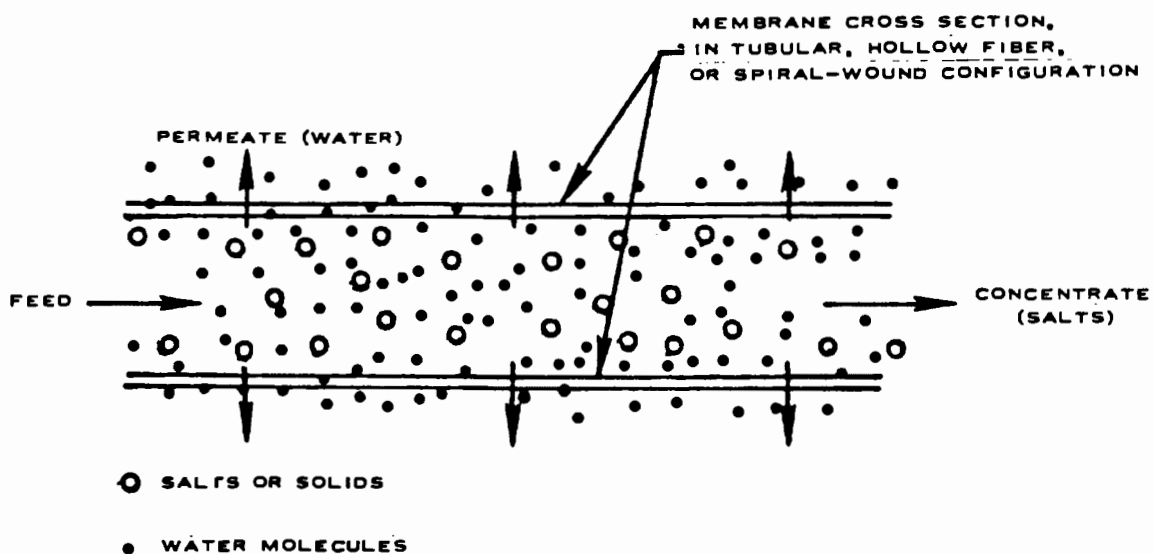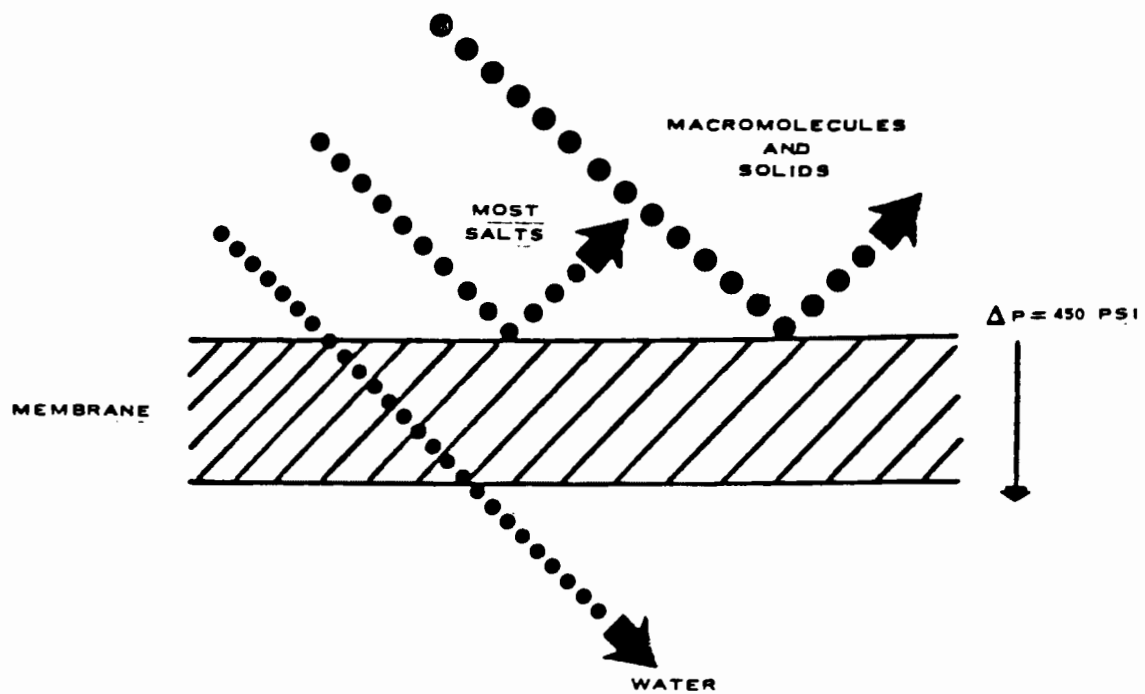
FIGURE VII-22

SIMPLIFIED REVERSE OSMOSIS SCHEMATIC
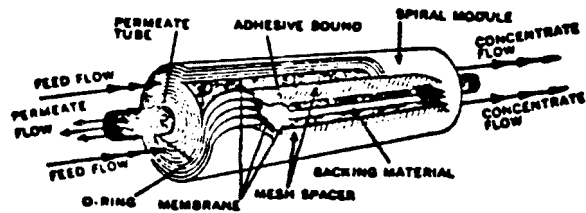
SPIRAL MEMBRANE MODULE
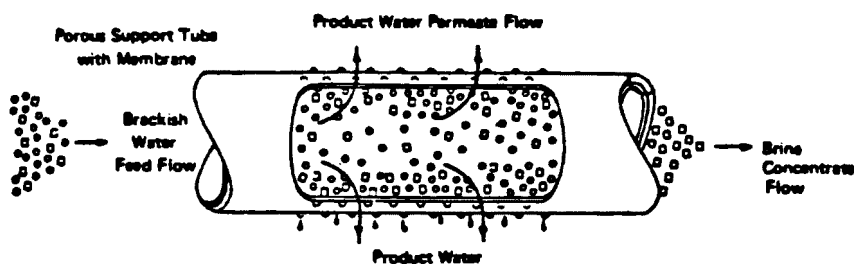
TUBULAR REVERSE OSMOSIS MODULE
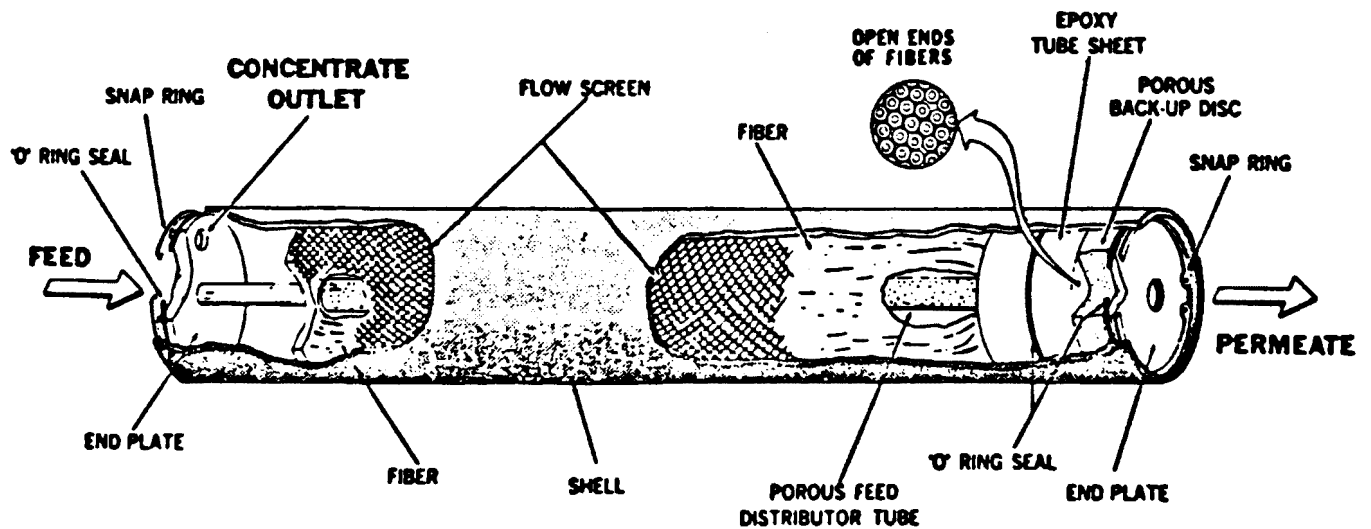
HOLLOW FIBER MODULE

FIGURE VII-23

REVERSE OSMOSIS MEMBRANE CONFIGURATIONS

OILY WATER INFLUENT

WATER DISCHARGE

MOTOR DRIVEN RAKE

OVERFLOW SHUTOFF VALVE

AIR IN

BACK PRESS VALVE

FINES & OIL OUT

EJECTOR

EXCESS AIR OUT LEVEL CONTROLLER

RECYCLE WATER

HOLDING TANK

TO SLUDGE TANK
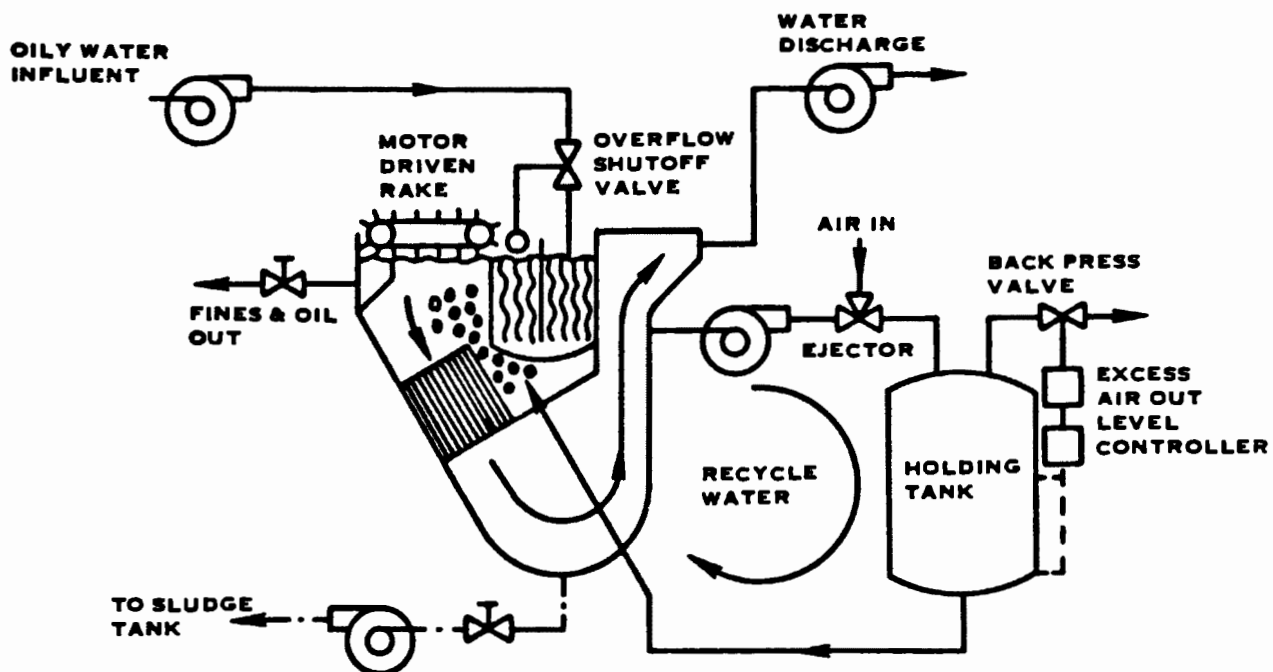
FIGURE VII-24

DISSOLVED AIR FLOTATION

594

ULTRAFILTRATION

MACROMOLECULES

P=10-50 PSI

MEMBRANE

WATER   SALTS

MEMBRANE

PERMEATE

FEED

CONCENTRATE

O   OIL PARTICLES   • DISSOLVED SALTS AND LOW-
MOLECULAR-WEIGHT ORGANICS
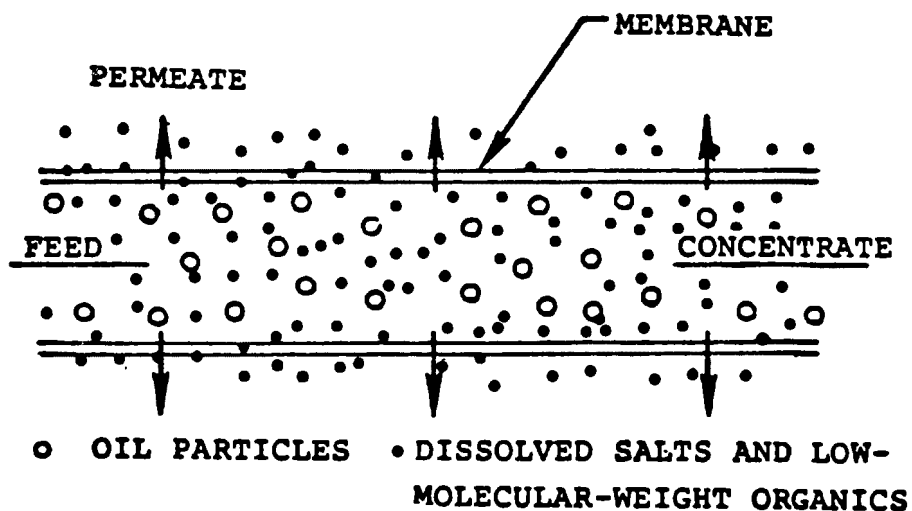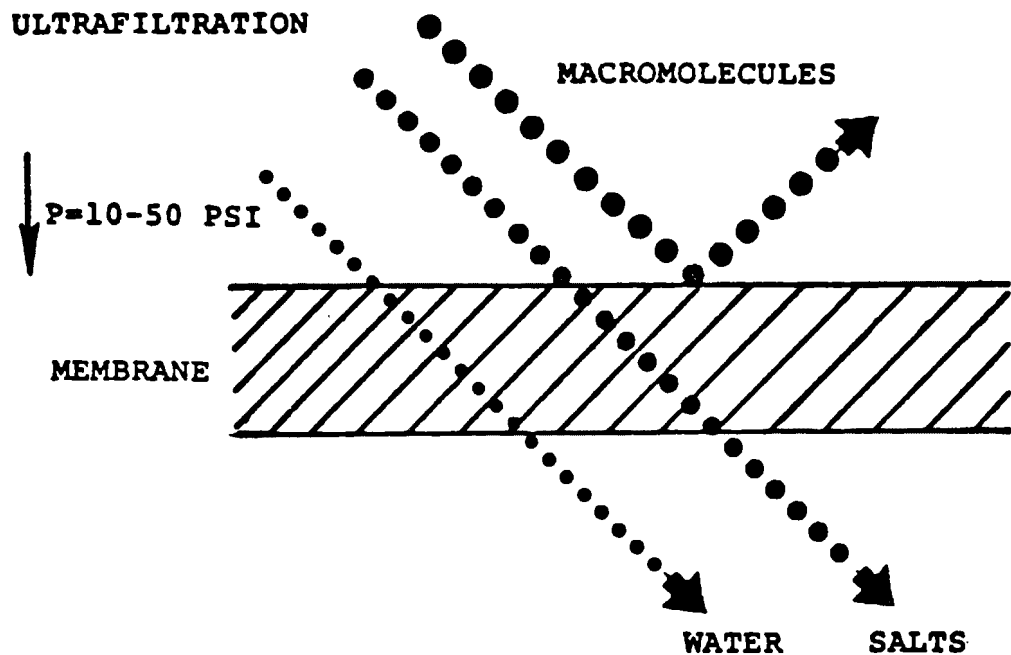
FIGURE VII-25
SIMPLIFIED ULTRAFILTRATION FLOW SCHEMATIC
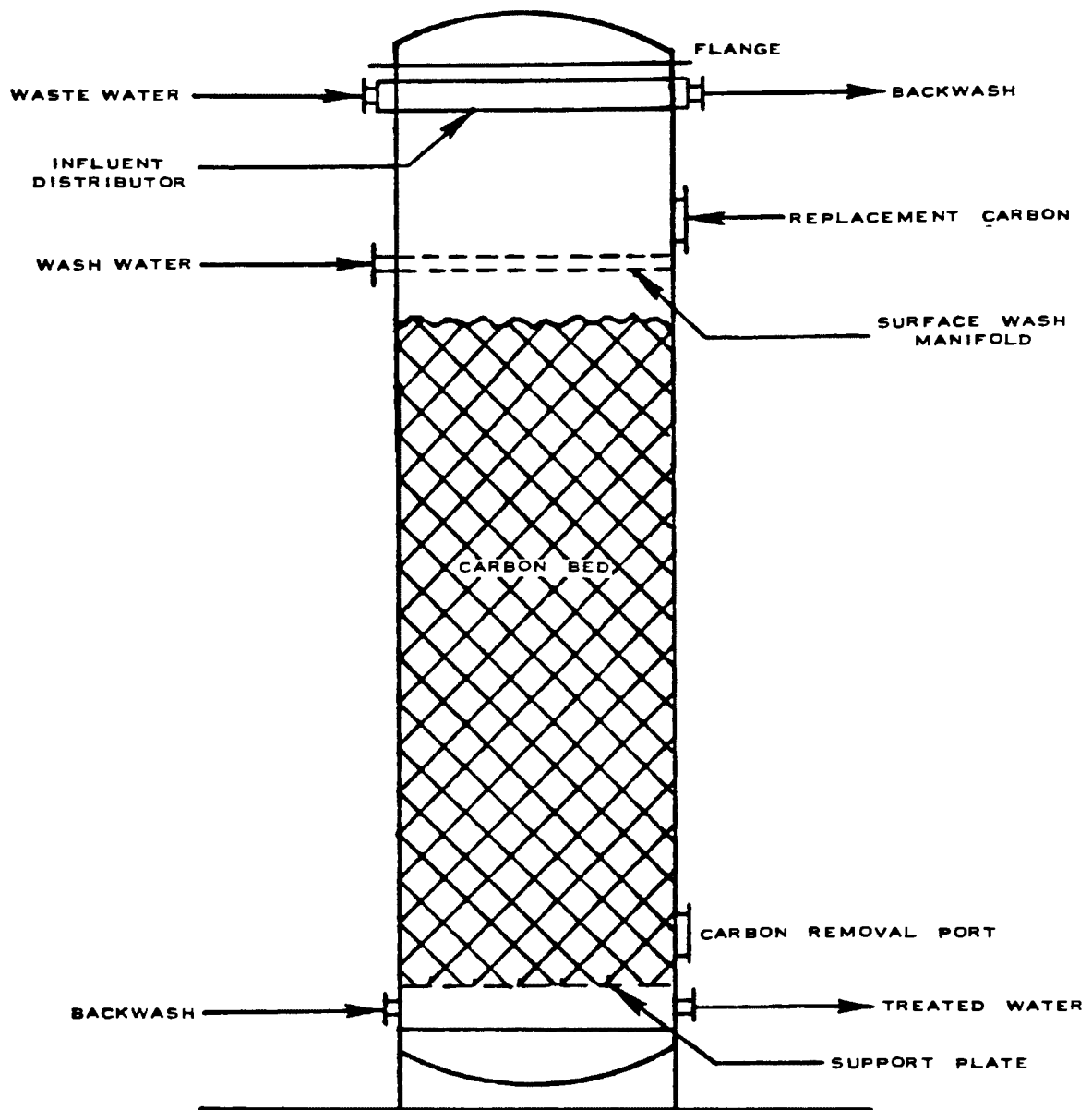
FIGURE VII-26
ACTIVATED CARBON ADSORPTION COLUMN
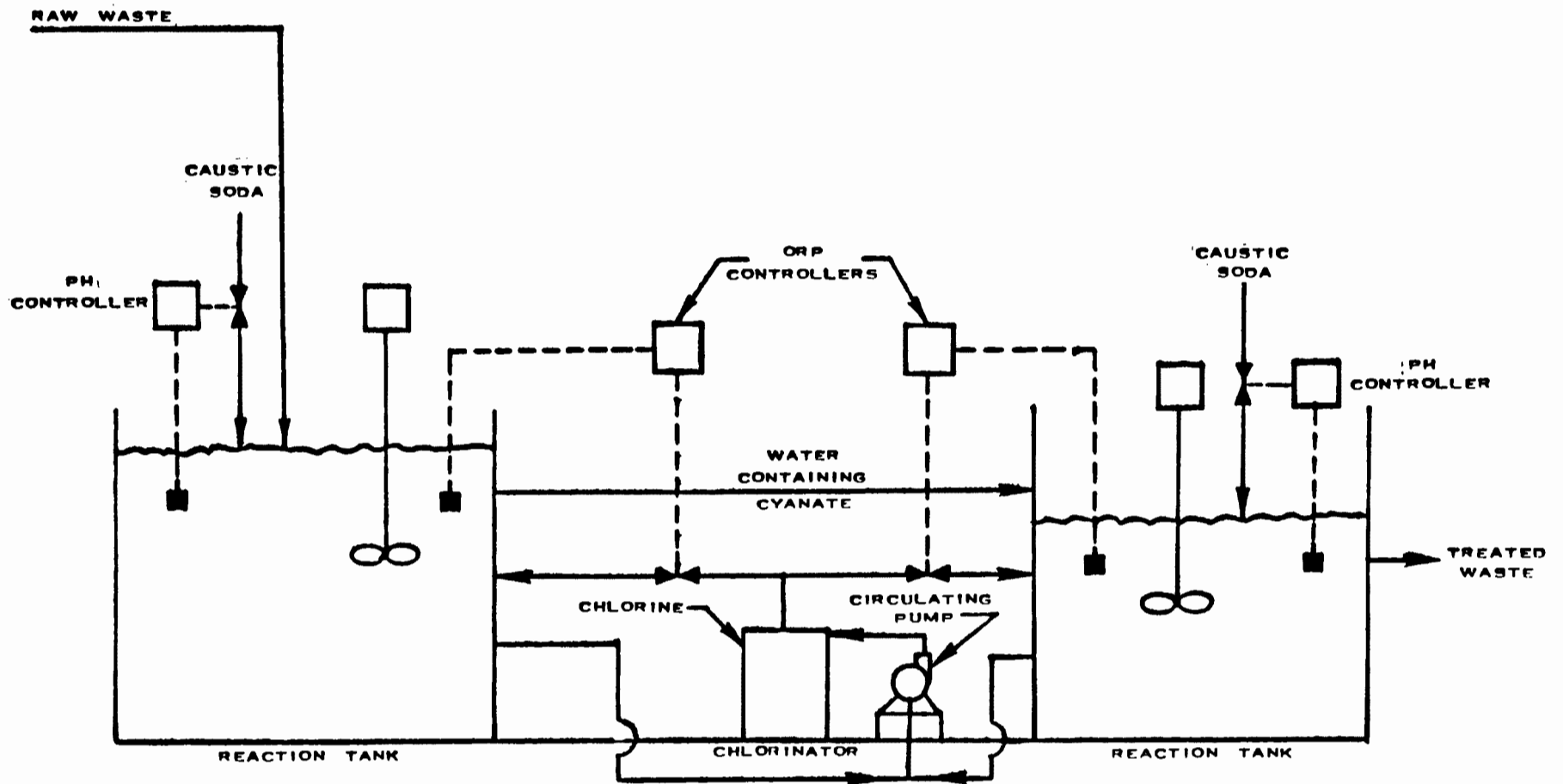
FIGURE V.-27
TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION
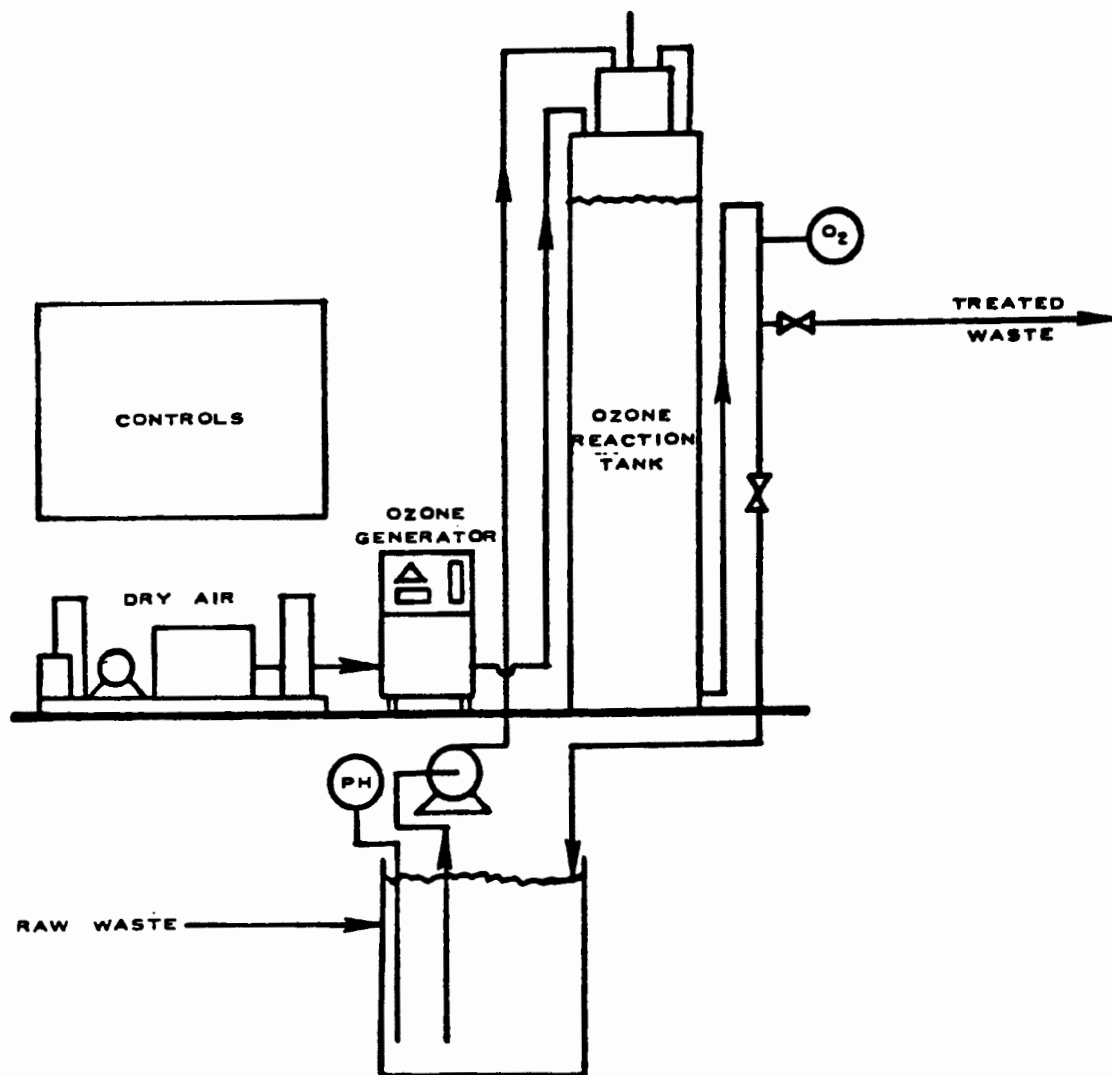
FIGURE VII-28

TYPICAL OZONE PLANT FOR WASTE TREATMENT

598
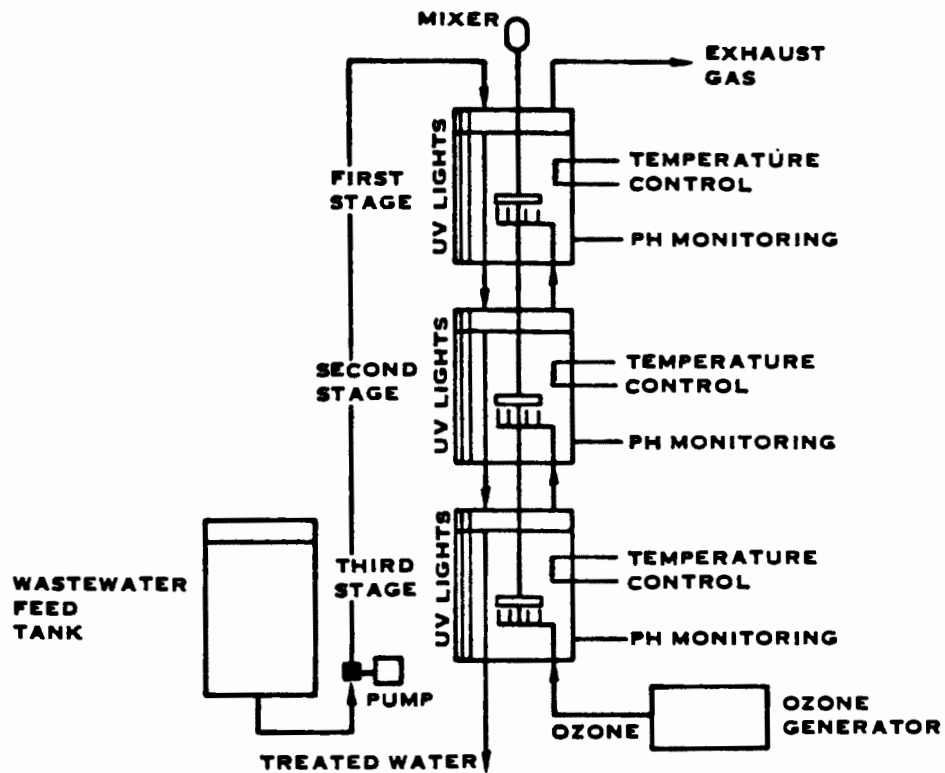
FIGURE VII-29

UV/OZONATION

599
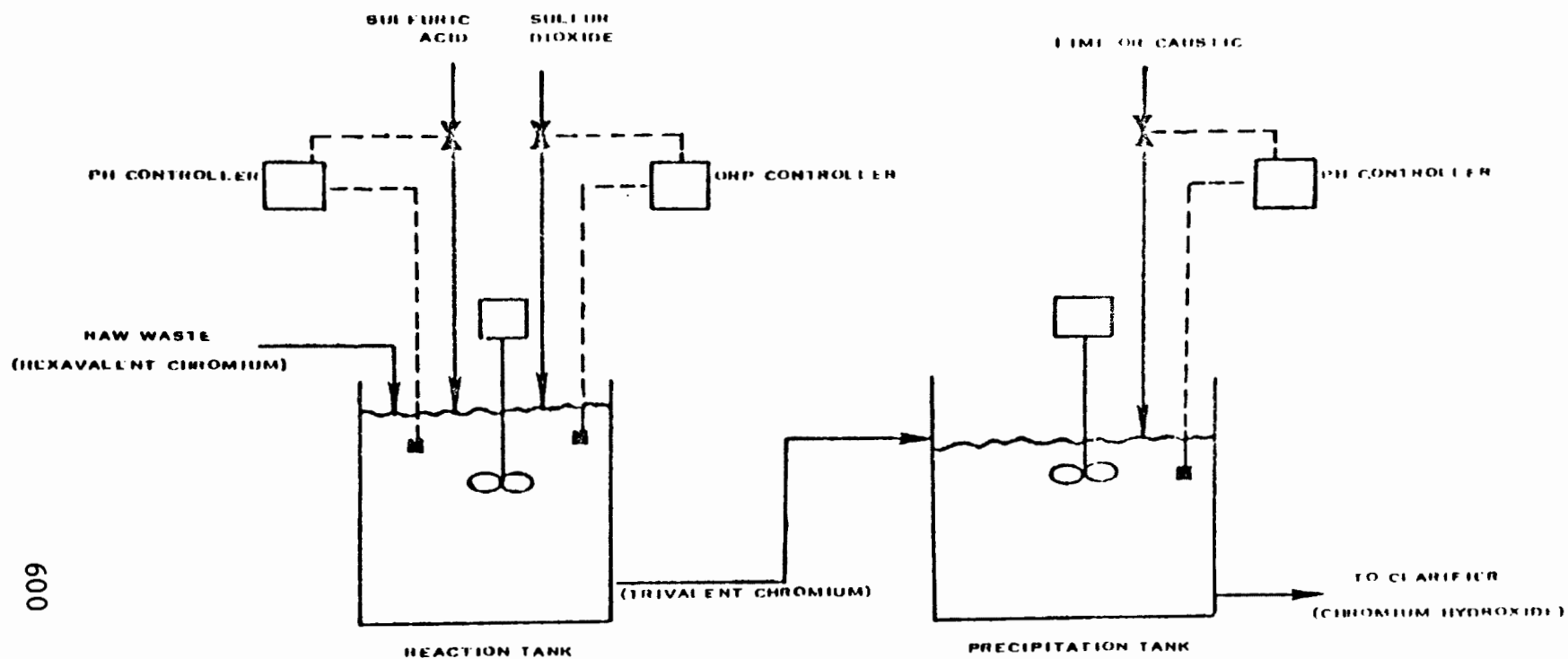
FIGURE VII-30

HEXAVALENT CHROMIUM REDUCTION WITH SULFUR DIOXIDE

TABLE VII-18

TREATABILITY RATING OF PRIORITY POLLUTANTS UTILIZING CARBON ADSORPTION

Priority Pollutant	*Removal Rating	Priority Pollutant	*Removal Rating
1. acenaphthene	H	49. trichlorofluoromethane	M
2. acrolein	L	50. dichlorodifluoromethane	L
3. acrylonitrile	L	51. chlorodibromomethane	M
4. benzene	M	52. hexachlorobutadiene	H
5. benzidine	H	53. hexachlorocyclopentadiene	H
6. carbon tetrachloride	M	54. isophorone	H
(tetrachloromethane)		55. naphthalene	H
7. chlorobenzene	H	56. nitrobenzene	H
8. 1,2,4-trichlorobenzene	H	57. 2-nitrophenol	H
9. hexachlorobenzene	H	58. 4-nitrophenol	H
10. 1,2-dichloroethane	M	59. 2,4-dinitrophenol	H
11. 1,1,1-trichloroethane	M	60. 4,6-dinitro-o-cresol	H
12. hexachloroethane	H	61. N-nitrosodimethylamine	M
13. 1,1-dichloroethane	M	62. N-nitrosodiphenylamine	H
14. 1,1,2-trichloroethane	M	63. N-nitrosodi-n-propylamine	M
15. 1,1,2,2-tetrachloroethane	H	64. pentachlorophenol	H
16. chloroethane	L	65. phenol	M
17. bis(chloromethyl)ether	-	66. bis(2-ethylhexyl)phthalate	H
18. bis(2-chloroethyl)ether	M	67. butyl benzyl phthalate	H
19. 2-chloroethyl vinyl ether	L	68. di-n-butyl phthalate	H
(mixed)		69. di-n-octyl phthalate	H
20. 2-chloronaphthalene	H	70. diethyl phthalate	H
21. 2,4,6-trichlorophenol	H	71. dimethyl phthalate	H
22. parachlorometa cresol	H	72. 1,2-benzanthracene (benzo	H
23. chloroform (trichloromethane)	L	(a)anthracene)	
24. 2-chlorophenol	H	73. benzo(a)pyrene (3,4-benzo-	H
25. 1,2-dichlorobenzene	H	pyrene)	
26. 1,3-dichlorobenzene	H	74. 3,4-benzofluoranthene	H
27. 1,4-dichlorobenzene	H	(benzo(b)fluoranthene)	
28. 3,3'-dichlorobenzidine	H	75. 11,12-benzofluoranthene	H
29. 1,1-dichloroethylene	L	(benzo(k)fluoranthene)	
30. 1,2-trans-dichloroethylene	L	76. chrysene	H
31. 2,4-dichlorophenol	H	77. acenaphthylene	H
32. 1,2-dichloropropane	M	78. anthracene	H
33. 1,2-dichloropropylene	M	79. 1,12-benzoperylene (benzo	H
(1,3,-dichloropropene)		(ghi)-perylene)	
34. 2,4-dimethylphenol	H	80. fluorene	H
35. 2,4-dinitrotoluene	H	81. phenanthrene	H
36. 2,6-dinitrotoluene	H	82. 1,2,5,6-dibenzanthracene	H
37. 1,2-diphenylhydrazine	H	(dibenzo (a,h) anthracene)	
38. ethylbenzene	M	83. indeno (1,2,3-cd) pyrene	H
39. fluoranthene	H	(2,3-o-phenylene pyrene)	
40. 4-chlorophenyl phenyl ether	H	84. pyrene	-
41. 4-bromophenyl phenyl ether	H	85. tetrachloroethylene	M
42. bis(2-chloroisopropyl)ether	M	86. toluene	M
43. bis(2-chloroethoxy)methane	M	87. trichloroethylene	L
44. methylene chloride	L	88. vinyl chloride	L
(dichloromethane)		(chloroethylene)	
45. methyl chloride (chloromethane)	L	106. PCB-1242 (Arochlor 1242)	H
46. methyl bromide (bromomethane)	L	107. PCB-1254 (Arochlor 1254)	H
47. bromoform (tribromomethane)	H	108. PCB-1221 (Arochlor 1221)	H
48. dichlorobromomethane	M	109. PCB-1332 (Arochlor 1232)	H
		110. PCB-1248 (Arochlor 1248)	H
		111. PCB-1260 (Arochlor 1260)	H
		112. PCB-1016 (Arochlor 1016)	H

* **NOTE:** Explanation of Removal Ratings

Category H (high removal)
    adsorbs at levels $\geq$ 100 mg/g carbon at C_f = 10 mg/l
    adsorbs at levels $\geq$ 100 mg/g carbon at C_f < 1.0 mg/l

Category M (moderate removal)
    adsorbs at levels $\geq$ 100 mg/g carbon at C_f = 10 mg/l
    adsorbs at levels $\leq$ 100 mg/g carbon at C_f < 1.0 mg/l

Category L (low removal)
    adsorbs at levels < 100 mg/g carbon at C_f = 10 mg/l
    adsorbs at levels < 10 mg/g carbon at C_f < 1.0 mg/l

C_f = final concentrations of priority pollutant at equilibrium

TABLE VII-19
CLASSES OF ORGANIC COMPOUNDS ADSORBED ON CARBON

Organic Chemical Class	Examples of Chemical Class
Aromatic Hydrocarbons	benzene, toluene, xylene
Polynuclear Aromatics	naphthalene, anthracene biphenyls
Chlorinated Aromatics	chlorobenzene, polychlorinated biphenyls, aldrin, endrin, toxaphene, DDT
Phenolics	phenol, cresol, resorcenol and polyphenyls
Chorinated Phenolics	trichlorophenol, pentachloro-phenol
*High Molecular Weight Aliphatic and Branch Chain hydrocarbons	gasoline, kerosine
Chlorinated Aliphatic hydrocarbons	carbon tetrachloride, perchloroethylene
*High Molecular Weight Aliphatic Acids and Aromatic Acids	tar acids, benzoic acid
*High Molecular Weight Aliphatic Amines and Aromatic Amines	aniline, toluene diamine
*High Molecular Weight Ketones, Esters, Ethers & Alcohols	hydroquinone, polyethylene glycol
Surfactants	alkyl benzene sulfonates
Soluble Organic Dyes	melkylene blue, Indigo carmine

* High Molecular Weight includes compounds in the broad range of from 4 to 20 carbon atoms

TABLE VII-21

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

EPA ID#	EQUIPMENT WASH&PASTE FORMULATION	WASTEWATER RECYCLE AND REUSE 1/ PROCESS SOLUTION	RINSES	SCRUBBER WASTE	PLAQUE SCRUBBING	COMBINED TREATED WASTE STREAMS IN-PROCESS	WATER USE REDUCTION DRY AIR POLLUTION CONTROL TECHNOLOGY	MULTI-STAGE COUNTER-CURRENT RINSE	DRY PLAQUE SCRUB TECHNIQUE	PROCESS MODIFICATION BATTERY WASH ELIMINATION	CONTACT COOLING ELIMINATION	FORMATION IN CASE (EXCEPT LEAD SUBCATEGORY)	DRY AMALGAMATION PROCESS	MATERIAL RECOVERY
Cadmium Subcategory														
		X			X									X
		X						X						
		X												
		X												
		X		X										X
							X							X
		X		X			X	X	X			X		X
							X							
Calcium Subcategory														
Lead Subcategory														
	X	X	X				X							X
	●	●				X								X
	●	X	X	X			X	X						X
	●	X		X			X							X
	X						X							
	●	X	X				X							X
	X	X												
	X						X							X
		X					X							X
	●	X	X				X			X				
	X						X				X			X
	●	X	●	X		X	X							X
						X	X			X				
				X			X			X				X
							X							
							X							X
		X	X				X							
		X					X							
	●													
							X							
	●	X		X			X	X						X
														X
	X						X							
	●	●	●			X	X							·X
	●	X		X			X	X						X

TABLE VII-24 (CONT'D.)

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

	WASTEWATER RECYCLE AND REUSE					WATER USE REDUCTION			PROCESS MODIFICATION				
EPA ID#	EQUIPMENT WASH&PASTE FORMULATION	PROCESS SOLUTION RINSES	SCRUBBER WASTE	PLAQUE SCRUBBING	COMBINED TREATED WASTE STREAMS IN-PROCESS	DRY AIR POLLUTION CONTROL TECHNOLOGY	MULTI-STAGE COUNTER-CURRENT RINSE	DRY PLAQUE SCRUB TECHNIQUE	BATTERY WASH ELIMI-NATION	CONTACT COOLING ELIMI-NATION	FORMATION IN CASE (EXCEPT LEAD SUB-CATEGORY)	DRY AMAL-GAMATION PROCESS	MATERIAL RECOVERY

Lead Subcategory Con't

	EQUIP WASH	PROC SOL	RINSES	SCRUBBER WASTE	PLAQUE SCRUB	COMBINED IN-PROC	DRY AIR POLL	MULTI-STAGE	DRY PLAQUE SCRUB	BATTERY WASH	CONTACT COOLING	FORMATION	DRY AMALG	MATERIAL RECOVERY
	X	X					X							X
	X	X	X				X							X
	■	X		X			X	X						X
	X	X					X							X
		X		X			X							
								X						
							X							X
	■	X		X			X							X
	X	X					X							X
	X	X					X							X
	X	X												
	X	X					X							X
		X												X
	X	X					X							X
		X					X							
		X												
	■		■			X	X							X
	X	X	X											
						X								
		X												
		X												
		X	X											
		X		X			X							X
	■	X		X			X							X
	X	X					X	X						X
	X	X												
		X					X							X
		X					X							
	X	X					X							X
	X	X												X
		X					X							
	■			X			X							X
	■	X	X	X			X	X						X
	X	X												X
			X											
		X	X				X	X						X
							X							X
	X	X									X			X
	■	X		X										X

TABLE VII-24 (CONT'D.)

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

EPA ID#	EQUIPMENT WASH&PASTE FORMULATION	PROCESS SOLUTION	RINSES	SCRUBBER WASTE	PLAQUE SCRUBBING	COMBINED TREATED WASTE STREAMS IN-PROCESS	DRY AIR POLLUTION CONTROL TECHNOLOGY	MULTI-STAGE COUNTER-CURRENT RINSE	DRY PLAQUE SCRUB TECHNIQUE	BATTERY WASH ELIMINATION	CONTACT COOLING ELIMINATION	FORMATION IN CASE (EXCEPT LEAD SUB-CATEGORY)	DRY AMALGAMATION PROCESS	MATERIAL RECOVERY
					WASTEWATER RECYCLE AND REUSE			WATER USE REDUCTION			PROCESS MODIFICATION			

Lead Subcategory Con't

EPA ID#	EQUIP. WASH&PASTE	PROCESS SOLUTION	RINSES	SCRUBBER WASTE	PLAQUE SCRUBBING	COMBINED IN-PROCESS	DRY AIR POLL.	MULTI-STAGE RINSE	DRY PLAQUE SCRUB	BATTERY WASH ELIM.	CONTACT COOLING ELIM.	FORMATION IN CASE	DRY AMALG.	MATERIAL RECOVERY
		X						X						X
			X											X
							X							
														X
		X												
		X												X
	X	X					X							X
	X									X				X
							X							X
		X												
	X	X					X							X
		X												
	X	X					X							X
	X	X	X					X		X				X
	X	X	X											
	X	X		X			X							X
	X													X
	X	X												X
							X							
							X							
	X	X	X				X							X
	X	X												X
	X	X		X			X							X
	X	X		X			X	X						X
		X												
	X	X		X			X	X						X
	X	X					X							
		X	X				X							X
		X					X							
	X	X												
	X	X					X							
	X	X	X			X	X							X
		X					X							
		X					X							
		X					X							
		X					X							

TABLE VII-24 (CONT'D.)

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

EPA ID#	WASTEWATER RECYCLE AND REUSE — EQUIPMENT WASH&PASTE FORMULATION	PROCESS SOLUTION RINSES	SCRUBBER WASTE	PLAQUE SCRUBBING	COMBINED TREATED WASTE STREAMS IN-PROCESS	WATER USE REDUCTION — DRY AIR POLLUTION CONTROL TECHNOLOGY	MULTI-STAGE COUNTER-CURRENT RINSE	DRY PLAQUE SCRUB TECHNIQUE	PROCESS MODIFICATION — BATTERY WASH ELIMINATION	CONTACT COOLING ELIMINATION	FORMATION IN CASE (EXCEPT LEAD SUB-CATEGORY)	DRY AMALGAMATION PROCESS	MATERIAL RECOVERY
Leclanche Subcategory													
	X					X							
	X					X							
Lithium Subcategory													X
Magnesium Subcategory						X							
Zinc Subcategory													
		X											X
		X								X			X
							X						
			X			X							
			X			X						X	
						X						X	X
			X									X	
												X	
		X				X						X	
		X				X	X					X	

NOTE: Each line represents one plant.

1/ Recycle or reuse following treatment
indicated by ⊗

SECTION VIII
COST OF WASTEWATER CONTROL AND TREATMENT

This section presents estimates of the cost of implementation of wastewater treatment and control options for each of the subcategories included in the battery manufacturing category. These cost estimates, together with the pollutant reduction performance estimates for each treatment and control option presented in Sections IX, X, XI, and XII provide a basis for evaluation of the options presented and identification of the best practicable control technology currently available (BPT), best available technology economically achievable (BAT), best demonstrated technology (BDT), and the best alternative for pretreatment. The cost estimates also provide the basis for the determination of the probable economic impact of regulation at different pollutant discharge levels on the battery manufacturing category. In addition, this section addresses non-water quality environmental impacts of wastewater treatment and control alternatives including air pollution, noise pollution, solid wastes, and energy requirements.

To arrive at the cost estimate presented in this section, specific wastewater treatment technologies and in-process control techniques from among those discussed in Section VII were selected and combined in wastewater treatment and control systems appropriate for each subcategory. As described in more detail below, investment and annual costs for each system were estimated based on wastewater flows and raw waste characteristics for each subcategory as presented in Section V. Cost estimates are also presented for individual treatment technologies included in the waste treatment systems.

COST ESTIMATION METHODOLOGY

Cost estimation is accomplished with the aid of a computer program which accepts inputs specifying the treatment system to be estimated, chemical characteristics of the raw waste streams treated, flow rates and operating schedules. The program accesses models for specific treatment components which relate component investment and operating costs, materials and energy requirements, and effluent stream characteristics to influent flow rates and stream characteristics. Component models are exercised sequentially as the components are encountered in the system to determine chemical characteristics and flow rates at each point. Component investment and annual costs are also determined and used in the computation of total system costs. Mass balance calculations are used to determine the characteristics of combined streams resulting from mixing two or more streams and to determine the volume of sludges or liquid wastes resulting from treatment operations such as sedimentation, filtration, flotation, and oil separation.

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Cost estimates are broken down into several distinct elements in addition to total investment and annual costs: operation and maintenance costs, energy costs, depreciation, and annual costs of capital. The cost estimation program incorporates provisions for adjustment of all costs to a common dollar base on the basis of economic indices appropriate to capital equipment and operating supplies. Labor and electrical power costs are input variables appropriate to the dollar base year for cost estimates. These cost breakdown and adjustment factors as well as other aspects of the cost estimation process are discussed in greater detail in the following paragraphs.

Cost Estimation Input Data

The waste treatment system descriptions input to the computer cost estimation program include both a specification of the waste treatment components included and a definition of their interconnections. For some components such as holding tanks, retention times or other operating parameters are also specified in the input, while for others, such as reagent mix tanks and clarifiers, these parameters are specified within the program based on prevailing design practice in industrial waste treatment. The waste treatment system descriptions may include multiple raw waste stream inputs and multiple treatment trains. For example, treatment for lead-acid battery manufacturing wastes includes segregation of wastewater from grid pasting operations and separate settling and recycle of these wastes in addition to chemical treatment of the remaining process wastewater.

The specific treatment systems selected for cost estimation for each subcategory were based on an examination of raw waste characteristics and consideration of manufacturing processes as presented in Section V, and an evaluation of available treatment technologies discussed in Section VII. The rationale for selection of these systems is presented in Section IX where pollution removal effectiveness is also addressed.

The input data set also includes chemical characteristics for each raw waste stream specified as input to the treatment systems for which costs are to be estimated. These characteristics are derived from the raw waste sampling data presented in Section V. The pollutant parameters which are presently accepted as input by the cost estimation program are shown in Table VIII-1 (Page 677). The values of these parameters are used in determining materials consumption, sludge volumes, treatment component sizes and effluent characteristics. The list of input parameters is expanded periodically as additional pollutants are found to be significant in waste streams from industries under study and as additional treatment technology cost and performance data become available. For the battery manufacturing category, individual subcategories commonly

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encompass a number of widely varying waste streams which are present to varying degrees at different facilities. The raw waste characteristics shown as input to waste treatment represent a mix of these streams including all significant pollutants generated in the subcategory and will not in general correspond precisely to process wastewater at any existing facility. The process by which these raw wastes were defined is explained in Section IX.

The final input data set comprises raw waste flow rates for each input stream for one or more plants in each subcategory addressed. Three cases corresponding to high, low and typical flows encountered at existing facilities were used for each battery manufacturing subcategory to represent the range of treatment costs which would be incurred in the implementation of each control and treatment option offered. In addition, data corresponding to the flow rates reported by each plant in the category were input to the computer to provide cost estimates for use in economic impact analysis.

System Cost Computation

A simplified flow chart for the estimation of wastewater treatment and control costs from the input data described above is presented in Figure VIII-1 (Page 677). In the computation, raw waste characteristics and flow rates for the first case are used as input to the model for the first treatment technology specified in the system definition. This model is used to determine the size and cost of the component, materials and energy consumed in its operation, and the volume and characteristics of the stream(s) discharged from it. These stream characteristics are then used as input to the next component(s) encountered in the system definition. This procedure is continued until the complete system costs and the volume and characteristics of the final effluent stream(s) and sludge or concentrated oil wastes have been determined. In addition to treatment components, the system may include mixers in which two streams are combined, and splitters in which part of a stream is directed to another destination. These elements are handled by mass balance calculations and allow cost estimation for specific treatment of segregated process wastes such as oxidation of cyanide bearing wastes prior to combination with other process wastes for further treatment, and representation of partial recycle of wastewater.

As an example of this computation process, the sequence of calculations involved in the development of cost estimates for the simple treatment system shown in Figure VIII-2 (Page 678) may be described. Initially, input specifications for the treatment system are read to set up the sequence of computations. The subroutine addressing chemical precipitation and clarification is then accessed. The sizes of the mixing tank and clarification basin are calculated based on the raw waste flow rate to provide 45 minute retention in the

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mix tank and 4 hour retention with 33.3 gph/ft² surface loading in the clarifier. Based on these sizes, investment and annual costs for labor, supplies and for the mixing tank and clarifier including mixers, clarifier rakes and other directly related equipment are determined. Fixed investment costs are then added to account for sludge pumps, controls and reagent feed systems.

Based on the input raw waste concentrations and flow rates, the reagent additions (lime, alum, and polyelectrolyte) are calculated to provide fixed concentrations of alum and polyelectrolyte and 10 percent excess lime over that required for stoichiometric reaction with the acidity and metals present in the waste stream. Costs are calculated for these materials, and the suspended solids and flow leaving the mixing tank and entering the clarifier are increased to reflect the lime solids added and precipitates formed. These modified stream characteristics are then used with performance algorithms for the clarifier (as discussed in Section VII) to determine concentrations of each pollutant in the clarifier effluent stream. By mass balance, the amount of each pollutant in the clarifier sludge may be determined. The volume of the sludge stream is determined by the concentration of TSS which is fixed at 4-5 percent based on general operating experience, and concentrations of other pollutants in the sludge stream are determined from their masses and the volume of the stream.

The subroutine describing vacuum filtration is then called, and the mass of suspended solids in the clarifier sludge stream is used to determine the size and investment cost of the vacuum filtration unit. Operating hours for the filter are calculated from the flow rate and TSS concentration and determine manhours required for operation. Maintenance labor requirements are added as a fixed additional cost.

The sludge flow rate and TSS content are then used to determine costs of materials and supplies for vacuum filter operation including iron and alum added as filter aids, and the electrical power costs for operation. Finally, the vacuum filter performance algorithms are used to determine the volume and characteristics of the vacuum filter sludge and filtrate, and the costs of contract disposal of the sludge are calculated. The recycle of vacuum filter filtrate to the chemical precipitation-clarification system is not reflected in the calculations due to the difficulty of iterative solution of such loops and the general observation that the contributions of such streams to the total flow and pollutant levels are in practice, negligibly small. Allowance for such minor contributions is made in the 20 percent excess capacity provided in most components.

The costs determined for all components of the system are summed and subsidiary costs are added to provide output specifying total investment and annual costs for the system and annual costs for

capital, depreciation, operation and maintenance, and energy. Costs for specific system components and the characteristics of all streams in the system may also be specified as output from the program.

In-Process Technologies

Costs calculated by the computer estimation procedure are highly dependent upon discharge flows produced by plants in the industry. As is described elsewhere in this document, the use of in-process technology to achieve flow reduction is highly cost effective. Reliance on the computer estimation procedure without attention to in-process technologies results in an overstatement of the cost required to achieve various levels of environmental improvement. For the cadmium, lead, Leclanche, and zinc subcategories there was sufficient data available from both visits and (dcp's) to estimate costs of treatment which include in-process control. Since each plant has a different process flow diagram, these calculations require extensive hand calculations to provide the relevant instrumentation, holding tanks, and process equipment appropriate to individual plants. Flows resulting from in-plant technology were then used as input to the computer. In the presentation of subcategory costs, costs are selected to provide a minimum cost (other than zero), where appropriate a median cost, and a maximum cost as realized in the subcategory. The flow rate associated with the cost is the flow to end-of-pipe treatment for the plant associated with the cost. In certain cases part of this flow may be recycled to the process.

Treatment Component Models

The cost estimation program presently incorporates subroutines providing cost and performance calculations for the treatment technologies identified in Table VIII-2 (Page 678). These subroutines have been developed over a period of years from the best available information including on-site observations of treatment system performance, costs, and construction practices at a large number of industrial facilities, published data, and information obtained from suppliers of wastewater treatment equipment. The subroutines are modified and new subroutines added as additional data allow improvements in treating technologies presently available, and as additional treatment technologies are required for the industrial wastewater streams under study. Specific discussion of each of the treatment component models used in costing wastewater treatment and control systems for the battery manufacturing category is presented later in this section.

In general terms, cost estimation is provided by mathematical relationships in each subroutine approximating observed correlations between component costs and the most significant operational parameters such as water flow rate, retention times, and pollutant

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concentrations.   In general, flow rate is the primary determinant of
investment costs and of most annual costs with the exception of
materials   costs.   In some cases, however, as discussed for the vacuum
filter, pollutant   concentrations   may   also   significantly   influence
costs.

Cost Factors and Adjustments

As previously indicated, costs are adjusted to a common dollar base
and are generally influenced by a number of factors including: Cost of
Labor, Cost of Energy, Capital Recovery Costs and Debt-Equity Ratio.
These cost adjustment and factors are discussed below.

Dollar Base - A dollar base of January 1978 was used for all costs.

Investment Cost Adjustment   -   Investment costs were adjusted to the
aforementioned dollar base by use of the Sewage Treatment Plant
Construction Cost Index.   This cost is published monthly by the EPA
Division of Facilities Construction and Operation.   The national
average of the Construction Cost Index for January 1978 was 288.0.

Supply Cost Adjustment - Supply costs such as chemicals were related
to the dollar base by the Wholesale Price Index.   This figure was
obtained   from   the   U.S.   Department   of   Labor,   Bureau   of   Labor
Statistics, "Monthly Labor Review".   For January 1978 the   "Industrial
Commodities" Wholesale Price Index was 201.6.   Process supply and
replacement costs were included in the estimate of the   total   process
operating and maintenance cost.

Cost of Labor - To relate the operating and maintenance labor costs,
the hourly wage rate for non-supervisory workers in water, stream, and
sanitary systems was used from the U.S. Department of Labor, Bureau of
Labor Statistics Monthly publication, "Employment and Earnings".   For
January 1978, this wage rate was $6.00 per hour.   This wage rate was
then applied to estimates of operation and maintenance man-hours
within each process to obtain process direct labor charges. To
account for indirect labor charges, 10 percent of the direct labor
costs was added to the direct labor charge to yield estimated total
labor costs. Such items as Social Security, employer contributions to
pension or retirement funds, and employer-paid premiums to various
forms of insurance programs were considered indirect labor costs.

Cost of Energy - Energy requirements were calculated directly within
each process.   Estimated costs were then determined by applying an
electrical rate of 3.3 cents per kilowatt hour.

The electrical charge for January 1978 was corroborated through
consultation with the Energy Consulting Services Department of the
Connecticut Light and Power Company.   This electrical charge was

determined by assuming that any electrical needs of a waste treatment facility or in-process technology would be satisfied by an existing electrical distribution system; i.e., no new meter would be required. This eliminated the formation of any new demand load base for the electrical charge.

Capital Recovery Costs - Capital recovery costs were divided into straight line ten-year depreciation and cost of capital at a ten percent annual interest rate for a period of ten years. The ten year depreciation period was consistent with the faster write-off (financial life) allowed for these facilities even though the equipment life is in the range of 20 to 25 years. The annual cost of capital was calculated by using the capital recovery factor approach.

The capital recovery factor (CRF) is normally used in industry to help allocate the initial investment and the interest to the total operating cost of the facility. It is equal to:

$$CRF = i + \frac{i}{(1+i)N-1}$$

where i is the annual interest rate and N is the number of years over which the capital is to be recovered. The annual capital recovery was obtained by multiplying the initial investment by the capital recovery factor. The annual depreciation of the capital investment was calculated by dividing the initial investment by the depreciation period N, which was assumed to be ten years. The annual cost of capital was then equal to the annual capital recovery minus the depreciation.

Debt-Equity Ratio - Limitations on new borrowings assume that debt may not exceed a set percentage of the shareholders equity. This defines the breakdown of the capital investment between debt and equity charges. However, due to the lack of information about the financial status of various plants, it was not feasible to estimate typical shareholders equity to obtain debt financing limitations. For these reasons, no attempt was made to break down the capital cost into debt and equity charges. Rather, the annual cost of capital was calculated via the procedure outlined in the Capital Recovery Costs section above.

Subsidiary Costs

The waste treatment and control system costs presented in Tables VIII-20 through VIII-43 (Pages 696 -719) for end-of-pipe and in-process waste water control and treatment systems include subsidiary costs associated with system construction and operation. These subsidiary costs include:

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- administration and laboratory facilities

- garage and shop facilities

- line segregation

- yardwork

- land

- engineering

- legal, fiscal, and administrative

- interest during construction

Administrative and laboratory facility investment is the cost of constructing space for administration, laboratory, and service functions for the wastewater treatment system. For these cost computations, it was assumed that there was already an existing building and space for administration, laboratory, and service functions. Therefore, there was no investment cost for this item.

For laboratory operations, an analytical fee of $90 (January 1978 dollars) was charged for each wastewater sample, regardless of whether the laboratory work was done on or off site. This analytical fee is typical of the charges experienced by EPA contractors during the past several years of sampling programs. The frequency of wastewater sampling is a function of wastewater discharge flow and is presented in Table VIII-3 (Page 679). This frequency was suggested by the Water Compliance Division of the USEPA.

For industrial waste treatment facilities being costed, no garage and shop investment cost was included. This cost item was assumed to be part of the normal plant costs and was not allocated to the wastewater treatment system.

Line segregation investment costs account for plant modifications to segregate wastes. The investment costs for line segregation included placing a trench in the existing plant floor and installing the lines in this trench. The same trench was used for all pipes and a gravity feed to the treatment system was assumed. The pipe was assumed to run from the center of the floor to a corner. A rate of 2.04 liters per hour of wastewater discharge per square meter of area (0.05 gallons per hour per square foot) was used to determine floor and trench dimensions from wastewater flow rates for use in this cost estimation process.

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The yardwork investment cost item includes the cost of general site clearing, intercomponent piping, valves, overhead and underground electrical wiring, cable, lighting, control structures, manholes, tunnels, conduits, and general site items outside the structural confines of particular individual plant components. This cost is typically 9 to 18 percent of the installed components investment costs. For these cost estimates, an average of 14 percent was utilized. Annual yardwork operation and maintenance costs are considered a part of normal plant maintenance and were not included in these cost estimates.

No new land purchases were required. It was assumed that the land required for the end-of-pipe treatment system was already available at the plant.

Engineering costs include both basic and special services. Basic services include preliminary design reports, detailed design, and certain office and field engineering services during construction of projects. Special services include improvement studies, resident engineering, soils investigations, land surveys, operation and maintenance manuals, and other miscellaneous services. Engineering cost is a function of process installed and yardwork investment costs and ranges between 5.7 and 14 percent depending on the total of these costs.

Legal, fiscal and administrative costs relate to planning and construction of waste water treatment facilities and include such items as preparation of legal documents, preparation of construction contracts, acquisition to land, etc. These costs are a function of process installed, yardwork, engineering, and land investment costs ranging between 1 and 3 percent of the total of these costs.

Interest cost during construction is the interest cost accrued on funds from the time payment is made to the contractor to the end of the construction period. The total of all other project investment costs (process installed; yardwork; land; engineering; and legal, fiscal, and administrative) and the applied interest affect this cost. An interest rate of 10 percent was used to determine the interest cost for these estimates. In general, interest cost during construction varies between 3 and 10 percent of total system costs depending on the total costs.

COST ESTIMATES FOR INDIVIDUAL TREATMENT TECHNOLOGIES

Table VIII-4 (Page 680) lists those technologies which are incorporated in the wastewater treatment and control options offered for the battery manufacturing category and for which cost estimates have been developed. These treatment technologies have been selected from among the larger set of available alternatives discussed in

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Section VII on the basis of an evaluation of raw waste characteristics, typical plant characteristics (e.g. location, production schedules, product mix, and land availability), and present treatment practices within the subcategories addressed. Specific rationale for selection is addressed in Sections IX, X, XI and XII. Cost estimates for each technology addressed in this section include investment costs and annual costs for depreciation, capital, operation and maintenance, and energy.

Investment – Investment is the capital expenditure required to bring the technology into operation. If the installation is a package contract, the investment is the purchase price of the installed equipment. Otherwise, it includes the equipment cost, cost of freight, insurance and taxes, and installation costs.

Total Annual Cost – Total annual cost is the sum of annual costs for depreciation, capital, operation and maintenance (less energy), and energy (as a separate function).

> Depreciation – Depreciation is an allowance, based on tax regulations, for the recovery of fixed capital from an investment to be considered as a non-cash annual expense. It may be regarded as the decline in value of a capital asset due to wearout and obsolescence.

> Capital – The annual cost of capital is the cost, to the plant, of obtaining capital expressed as an interest rate. It is equal to the capital recovery cost (as previously discussed on cost factors) less depreciation.

> Operation and Maintenance – Operation and maintenance cost is the annual cost of running the wastewater treatment equipment. It includes labor and materials such as waste treatment chemicals. As presented on the tables, operation and maintenance cost does not include energy (power or fuel) costs because these costs are shown separately.

> Energy – The annual cost of energy is shown separately, although it is commonly included as part of operation and maintenance cost. Energy cost has been shown separately because of its importance to the nation's economy and natural resources.

Lime Precipitation and Clarification

This technology removes dissolved pollutants by the formation of precipitates by reaction with added lime and subsequent removal of the precipitated solids by gravity settling in a clarifier. Several distinct operating modes and construction techniques are costed to provide least cost treatment over a broad range of flow rates.

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Because of their interrelationships and integration in common equipment in some installation, both the chemical addition and solids removal equipment are addressed in a single subroutine.

Investment Cost - Investment costs are determined for this technology for continuous treatment systems and for batch treatment. The least cost system is selected for each application. Continuous treatment systems include controls, reagent feed equipment, a mix tank for reagent feed addition and a clarification basin with associated sludge rakes and pumps. Batch treatment includes only reaction-settling tanks and sludge pumps.

Controls and reagent feed equipment: costs for continuous treatment systems include a fixed charge of $9075 covering an immersion pH probe and transmitter, pH monitor, controller, lime slurry pump, 1 hp mixer, and transfer pump. In addition, an agitated storage tank sufficient to hold one days operating requirements of a 30 percent lime slurry is included. Costs for this tank are estimated based on the holding tank costs discussed later in this section and shown in Figure VIII-17 (Page 659). Lime feed to the slurry tank is assumed to be manual. Hydrated lime is used and no equipment for lime slaking or handling is included in these cost estimates. At facilities with high lime consumption mechanical lime feed may be used resulting in higher investment costs, but reduced manpower requirements in comparison to manual addition.

Mix Tank: Continuous systems also include an agitated tank providing 45 minutes detention for reagent addition and formation of precipitates.

Clarifier: The clarifier size is calculated based on a hydraulic loading of 33.3 gph/ft^2 and a retention time of 4 hours with a 20 percent allowance for excess flow capacity. Costs include both the settling basin or tank and sludge collection mechanism. Investment costs as a function of flow rate are shown in Figure VIII-3 (Page 645). The type of construction used is selected internally in the cost estimation program to provide least cost.

Sludge Pumps: A cost of $3202 is included in the total capital cost estimates regardless of whether steel or concrete construction is used. This cost covers the expense for two centrifugal sludge pumps.

To calculate the total capital cost for continuous lime precipitation and clarification, the costs estimated for the controls and reagent feed system, mix tank, clarifier and sludge pump must be summed.

For batch treatment, dual above-ground cylindrical carbon steel tanks sized for 8 hour retention and 20 percent excess capacity are used. If the batch flow rate exceeds 5204 gph, then costs for fabrication

are included. The capital cost for the batch system (not including the sludge pump costs) is shown in Figure VIII-4 (Page 646). To complete the capital cost estimation for batch treatment, a fixed $3,202 cost is included for sludge pumps as discussed above.

Operation & Maintenance Costs

The operation and maintenance costs for the Chemical Precipitation-Clarification routine include:

1) Cost of chemicals added (lime, alum, and polyelectrolyte)
2) Labor (operation and maintenance)
3) Energy

Each of these contributing factors is discussed below.

. CHEMICAL COST

Lime, alum and polyelectrolyte are added for metals and solids removal. The amount of lime required is based on equivalent amounts of various pollutant parameters present in the stream entering the clarifier unit. The methods used in determining the lime requirements are shown in Table VIII-5 (Page 681). Alum and polyelectrolyte additions are calculated to provide a fixed concentration of 200 mg/l of alum and 1 mg/l of polyelectrolyte.

. LABOR

Figure VIII-5 (Page 647) presents the manhour requirements for the continuous clarifier system. For the batch system, maintenance labor is assumed negligible and operation labor is calculated from:

(man-hours for operation) = 390 + (0.975) x (lbs. lime added per day)

. ENERGY

The energy costs are calculated from the clarifier and sludge pump horsepower requirements.

Continuous Mode

The clarifier horsepower requirement is assumed constant over the hours of operation of the treatment system at a level of 0.0000265 horsepower per 1 gph of flow influent to the clarifier. The sludge pumps are assumed operational for 5 minutes of each operational hour at a level of 0.00212 horsepower per 1 gph of sludge stream flow.

Batch Mode

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The clarifier horsepower requirement is assumed to occur for 7.5 minutes per operation hour at the following levels:

influent flow < 1042 gph; 0.0048 hp/gph
influent flow ≥ 1042 gph; 0.0096 hp/gph

The power required for the sludge pumps in the batch system is the same as that required for the sludge pumps in the continuous system.

Given the above requirements, operation and maintenance costs are calculated based on the following:

- $6.00 per man-hour + 10 percent indirect labor charge
- $41.26/ton of lime
- $44.91 ton of alum
- $3.59/lb of polyelectrolyte
- $0.032/kilowatt-hour of required electricity

Sulfide Precipitation - Clarification

This technology removes dissolved pollutants by the formation of precipitates by reaction with sodium sulfide, sodium bisulfide, or ferrous sulfide and lime, and subsequent removal of the precipitates by settling. As discussed for lime precipitation and clarification, the addition of chemicals, formation of precipitates, and removal of the precipitated solids from the wastewater stream are addressed together in cost estimation because of their interrelationships and commonality of equipment under some circumstances.

Investment Cost. Capital cost estimation procedures for sulfide precipitation and clarification are identical to those for lime precipitation and clarification. Continuous treatment systems using concrete and steel construction and batch treatment systems are costed to provide a least cost system for each flow range and set of raw waste characteristics. Cost factors are also the same as for lime precipitation and clarification.

Operation and Maintenance Costs. Costs estimated for the operation and maintenance of a sulfide precipitation and clarification system are also identical to those for lime precipitation and clarification except for the cost of treatment chemicals. Lime is added prior to sulfide precipitation to achieve an alkaline pH of approximately 8.5-9 and will lead to the precipitation of some pollutants as hydroxides or calcium salts. Lime consumption based on both neutralization and formation of precipitates is calculated to provide a 10 percent excess over stochiometric requirements. Sulfide costs are based on the addition of ferrous sulfate and sodium bisulfide (NaHS) to form a 10 percent excess of ferrous sulfide over stoichiometric requirements for precipitation. Reagent additions are calculated as shown in Table

VIII-6 (Page 682). Addition of alum and polyelectrolyte is identical to that shown for lime precipitation and clarification as are labor and energy rates.

The following rates are used in determining operating and maintenance costs for this technology.

- $6.00 per man-hour + 10 percent indirect labor charge
- $44.91/ton of alum
- $3.59/lb of polyelectrolyte
- $41.26/ton of lime
- $0.27/lb of sodium bisulfide
- $143.74/ton of ferrous sulfate
- $0.032/kilowatt-hour of electricity

Multi-Media Filtration

This technology provides removal of suspended solids by filtration through a bed of particles of several distinct size ranges. As a polishing treatment after chemical precipitation and clarification processes, multi-media filtration provides improved removal of precipitates and thereby improved removal of the original dissolved pollutants.

Capital Cost. The size of the multi-media filtration unit is based on 20 percent excess flow capacity and a hydraulic loading of 0.5 ft^2/gpm. The capital cost, presented in Figure VIII-6 (Page 648) as a function of flow rate, includes a backwash mechanism, pumps, controls, media and installation.

Operation And Maintenance. The costs shown in Figure VIII-6 (Page 648) for annual costs includes contributions of materials, electricity and labor. These curves result from correlations made with data obtained from a major manufacturer. Energy costs are estimated to be 3 percent of total O&M.

Membrane Filtration

Membrane filtration includes addition of sodium hydroxide to form metal precipitates and removal of the resultant solids on a membrane filter. As a polishing treatment, it minimizes solubility of metal and provides highly effective removal of precipitated hydroxides and sulfides.

Capital Cost. Based on manufacturer's data, a factor of $52.6 per 1 gph flow rate to the membrane filter is used to estimate capital cost. Capital cost includes installation.

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Operation and Maintenance Cost. The operation and maintenance costs for membrane filtration include:

  1) Labor
  2) Sodium Hydroxide Added
  3) Energy

Each of these contributing factors are discussed below.

. LABOR

  2 man-hours per day of operation are included.

. SODIUM HYDROXIDE ADDITION

Sodium hydroxide is added to precipitate metals as hydroxides or to insure a pH favorable to sulfide precipitation. The amount of sodium hydroxide required is based on equivalent amounts of various pollutant parameters present in the stream entering the membrane filter. The method used to determine the sodium hydroxide demand is shown below:

POLLUTANT	ANaOH
Chromium, Total	0.000508
Copper	0.000279
Acidity	0.000175
Iron, DIS	0.000474
Zinc	0.000268
Cadmium	0.000158
Cobalt	0.000301
Manganese	0.000322
Aluminum	0.000076

(Sodium Hydroxide Per Pollutant, lb/day) = ANaOH x Flow Rate (GPH) x Pollutant Concentration (mg/l)

. ENERGY

  The horsepower required is as follows:

  two 1/2 horsepower mixers operating 34 minutes per operational hour

  two one horsepower pumps operating 37 minutes per operational hour

  one 20 horsepower pump operating 45 minutes per operational hour

Given the above requirements, operation and maintenance costs are calculated based on the following:

- $6.00 per man-hour + 10 percent indirect labor charge
- $0.11 per pound of sodium hydroxide required
- $0.032 per kilowatt-hour of energy required calculated costs in the battery industry as a function of flow rate for membrane filtration are presented in Figure VII-7.

Reverse Osmosis

This technology achieves the concentration of dissolved organic and inorganic pollutants in wastewater by forcing the water through semi-permeable membranes which will not pass the pollutants. The water which permeates the membranes is relatively free of contaminants and suitable for reuse in most manufacturing process operations. A number of different membrane types and constructions are available which are optimized for different wastewater characteristics (especially pH and temperature). Two variations, one suited specifically to recovery of nickel plating solutions, and the other of more general applicability are addressed in cost and performance models.

Capital Cost. Investment cost data from several manufacturers of RO equipment is summarized in the cost curve shown in Figure VIII-8 (Page 650). The cost shown include a prefilter, chemical feed system, scale inhibitor tank, high pressure pump, and permeators. Installation is also included. Two different systems, one using cellulose acetate membranes and suitable for nickel plating bath recovery, and one using polyamide membranes which are tolerant of a wider pH and temperature range are addressed. The polyamide resin systems are applicable to treatment of battery manufacturing wastewaters.

Operation and Maintenance Cost. Contributions to operation and maintenance costs include:

- LABOR

The annual labor requirement is shown in Figure VIII-9 (Page 651). Labor cost is calculated using a $6.00 per hour labor rate plus a 10 percent indirect labor charge.

- MATERIALS

The annual cost of materials used in operation and maintenance of the reverse osmosis unit is shown in Figure VIII-10 (Page 652). The major component of the materials cost is the cost of replacement of permeator modules which are assumed to have a 1.5 year service life based on manufacturers' data.

- POWER

The horsepower requirements for reverse osmosis unit is shown in Figure VIII-11 (Page 653). This requirement is assumed to be constant over the operating hours of the system being estimated. The energy cost is determined using a charge of $0.032 per kilowatt-hour.

Vacuum Filtration

Vacuum filtration is widely used to reduce the water content of high solids streams. In the battery manufacturing industry, this technology is applied to dewatering sludge from clarifiers, membrane filters and other waste treatment units.

Capital Cost. The vacuum filter is sized based on a typical loading of 14.6 kilograms of influent solids per hour per square meter of filter area (3 lbs/ft^2-hr). The curves of cost versus flow rate at TSS concentrations of 3 percent and 5 percent are shown in Figure VIII-12 (Page 654). The capital cost obtained from this curve includes installation costs.

Operation and Maintenance Cost

. LABOR

The vacuum filtration subroutine may be run for off-site sludge disposal or for on-site sludge incineration. For on-site sludge incineration, conveyor transport is assumed, and operating man-hours are reduced from those for off-site disposal. The required operating hours per year varies with both flow rate and the total suspended solids concentration both flow rate and the total suspended solids concentration in the influent stream. Figure VIII-13 (Page 655) shows the variance of operating hours with flow rate and TSS concentration. Maintenance labor for either sludge disposal mode is fixed at 24 manhours per year.

. MATERIALS

The cost of materials and supplies needed for operation and maintenance includes belts, oil, grease, seals, and chemicals required to raise the total suspended solids to the vacuum filter. The amount of chemicals required (iron and alum) is based on raising the TSS concentration to the filter by 1 mg/l. Costs of materials required as a function of flow rate and unaltered TSS concentrations is presented in Figure VIII-14 (Page 656).

. ENERGY

Electrical costs needed to supply power for pumps and controls is presented in Figure VIII-15 (Page 657). As the required horsepower of

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the pumps is dependent on the influent TSS level, the costs are presented as a function of flow rate and TSS level.

Holding Tanks

Tanks serving a variety of purposes in wastewater treatment and control systems are fundamentally similar in design and construction and in cost. They may include equalization tanks, solution holding tanks, slurry or sludge holding tanks, mixing tanks, and settling tanks from which sludge is intermittently removed manually or by sludge pumps. Tanks for all of these purposes are addressed in a single cost estimation subroutine with additional costs for auxilliary equipment such as sludge pumps added as appropriate.

Capital Costs. Costs are estimated for either steel or concrete tanks. Tank construction may be specified as input data, or determined on a least cost basis. Retention time is specified as input data and, together with stream flow rate, determines tank size. Capital costs for tanks sized for 20 percent excess capacity are shown as functions of volume in Figure VIII-16 (Page 658).

Operation and Maintenance Costs. For all holding tanks except sludge holding tanks, operation and maintenance costs are minimal in comparison to other system O&M costs. Therefore only energy costs for pump and mixer operation are determined. These energy costs are presented in Figure VIII-17 (Page 659).

For sludge holding tanks, additional operation and maintenance labor requirements are reflected in increased O&M costs. The required manhours used in cost estimation are presented in Figure VIII-18 (Page 660). Labor costs are determined using a labor rate of $6.00 per manhour plus 10 percent indirect labor charge.

Where tanks are used for settling as in lime precipitation and clarification batch treatment, additional operation and maintenance costs are calculated as discussed specifically for each technology.

pH Adjustment

The adjustment of pH values is a necessary precursor to a number of treatment operations and is frequently required to return waste streams to a pH value suitable for discharge following metals precipitation. This is typically accomplished by metering an alkaline or acid reagent into a mix tank under automatic feedback control.

Figure VIII-19 (Page 661) presents capital costs for pH adjustment as a function of the flow rate going into the units. The cost calculations are based on steel or concrete tanks with a 15 minute retention time and an excess capacity of 20 percent. Tank

construction is selected on a least cost basis. Costs include a pH probe and control system, reagent mix tanks, a mixer in the pH adjustment tank, and system installation.

Operation and Maintenance Costs

. LABOR

The required man-hours as a function of flow rate is presented in Figure VIII-20 (Page 662.). The cost of labor may be calculated using a labor rate of $6.00 per hour plus a 10 percent indirect labor charge.

. MATERIALS

Sodium hydroxide or sulfuric acid are added according to the stream pH, and acidity or alkalinity. The amount of lime or acid required may be calculated by the procedure shown in Table VIII-7 (Page 683). The cost of lime or acid added may be determined using the rates of $0.11 per pound of sodium hydroxide and $70.0 per ton of sulfuric acid.

. ENERGY

Power, required for a mixer, is based on a representative installation with 1-turnover per minute. The daily horsepower requirement is 3 hp per 10,000 gph flow rate. The energy cost may be calculated using the rates of .8 kilowatts per horsepower and $.032 per kilowatt-hour.

Contract Removal

Sludge, waste oils, and in some cases concentrated waste solutions frequently result from wastewater treatment processes. These may be disposed of on-site by incineration, landfill or reclamation, but are most often removed on a contract basis for off-site disposal. System cost estimate presented in this report are based on contract removal of sludges and waste oils. In addition, where only small volumes of concentrated wastewater are produced, contract-removal for off-site treatment may represent the most cost-effective approach to water pollution abatement. Estimates of solution contract haul costs are also provided by this subroutine and may be selected in place of on-site treatment on a least-cost basis.

Capital Costs – Capital investment for contract removal is zero.

Operating Costs – Annual costs are estimated for contract removal of total waste streams or sludge and oil streams as specified in input data. Sludge and oil removal costs are further divided into wet and dry haulage depending upon whether or not upstream sludge dewatering

is provided. The use of wet haulage or of sludge dewatering and dry haulage is based on least cost as determined by annualized system costs over a ten year period. Wet haulage costs are always used in batch treatment systems and when the volume of the sludge stream is less than 100 gallons per day. Both wet sludge haulage and total waste haulage differ in cost depending on the chemical composition of the water removed. Wastes are classified as cyanide bearing, hexavalent chromium bearing, or oily and assigned different haulage costs as shown below.

Waste Composition	Haulage Cost
$\geq .05$ mg/l CN-	$0.45/gallon
$\geq .1$ mg/l Cr+6	$0.20/gallon
Oil & grease $\geq$ TSS	$0.12/gallon
All others	$0.16/gallon

Dry sludge haul costs are estimated at $0.12/gallon and 40 percent dry solids in the sludge.

Carbon Adsorption

This technology removes organic and inorganic pollutants and suspended solids by pore adsorption, surface reactions, physical filtering by carbon grains, and in some cases as part of a biological treatment system. It typically follows other types of treatment as a means of polishing effluent. A variety of carbon adsorption systems exist: upflow, downflow, packed bed, expanded bed, regenerative and throwaway. Regeneration of carbon requires an expensive furnace and fuel. As a general criteria, it is not economically feasible to install a thermal regeneration system unless carbon usage is above 1000 lbs per day.

Capital Costs

Capital costs estimated for carbon adsorption systems applied to battery manufacturing wastewater are provided in Figure VIII-21 (Page 663) and assume a packed bed throwaway system. All equipment costs are based on the EPA Technology Transfer Process Design Manual Carbon Adsorption and include a contactor system, a pump station, and initial carbon. Costs for carbon adsorption are highly variable and it is usually cost effective to pretreat waste before using carbon. The high cost of removing a small amount of a given priority pollutant results from the requirement that the system must be sized and operated to remove all organics present which are more easily removed than the species of interest. Accuracy of model predictions depends upon the estimate of other organics present. Removal efficiencies depend upon the type of carbon used and a mixture of carbon types may be cost beneficial. Where regenerative systems are considered, it is

important to distinguish between removals achieved using regenerated carbon and fresh carbon which are vastly different. Equipment sizing is based on dynamic (as opposed to carbon isotherm) studies.

Operation and Maintenance Costs

The chief operation and maintenance costs are labor, replacement carbon, and electricity for the pump station. Annual costs determined for battery manufacturing applications are shown in Figure VIII-21 (Page 663). Carbon usage selected to provide 99 percent removal of each organic priority pollutant is determined from a reciprocal carbon efficiency of an appropriate mix of carbons (bituminous and lignite) estimated at 0.2 ft³ of fresh unregenerated (virgin) carbon per pound of organics provided by the influent. Carbon is costed at $1.19/lb and electricity at $0.033/kw hr.

Chromium Reduction

This technology provides chemical reduction of hexavalent chromium under acid conditions to allow subsequent removal of the trivalent form by precipitation as the hydroxide. Treatment may be provided in either continuous or batch mode, and cost estimates are developed for both. Operating mode for system cost estimates is selected on a least cost basis.

Capital Cost. Cost estimates include all required equipment for performing this treatment technology including reagent feed, reaction tanks, mixers and controls. Different reagents are provided for batch and continuous treatment resulting in different system design considerations as discussed below.

For both continuous and batch treatment, sulfuric acid is added for pH control. A 90-day supply is stored in the 25 percent aqueous form in an above-ground, covered concrete tank, 0.305 m(1 ft) thick.

For continuous chromium reduction the single chromium reduction tank is sized as an above-ground cylindrical concrete tank with a 0.305 m (1 ft) wall thickness, a 54 minute retention time, and an excess capacity factor of 1.2. Sulfur dioxide is added to convert the influent hexavalent chromium to the trivalent form.

The control system for continuous chromium reduction consists of:

1   immersion pH probe and transmitter
1   immersion ORP probe and transmitter
1   pH and ORP monitor
2   slow process controllers
1   sulfonator and associated pressure regulator
1   sulfuric acid pump

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1   transfer pump for sulfur dioxide ejector
2   maintenance kits for electrodes, and miscellaneous
    electrical equipment and piping

For batch chromium reduction, the dual chromium reduction tanks are sized as above-ground cylindrical concrete tanks, 0.305 m (1 ft) thick, with a 4 hour retention time, an excess capacity factor of 0.2. Sodium bisulfite is added to reduce the hexavalent chromium.

A completely manual system is provided for batch operation. Subsidiary equipment includes:

1   sodium bisulfite mixing and feed tank
1   metal stand and agitator collector
1   sodium bisulfite mixer with disconnects
1   sulfuric acid pump
1   sulfuric acid mixer with disconnects
2   immersion pH probes
1   pH monitor, and miscellaneous piping

Capital costs for batch and continuous treatment systems are presented in Figure VIII-22 (Page 664).

Operation and Maintenance. Costs for operating and maintaining chromium reduction systems include labor, chemical addition, and energy requirements. These factors are determined as follows:

.   Labor

The labor requirements are plotted in Figure VIII-23 (Page 665). Maintenance of the batch system is assumed negligible and so it is not shown.

.   Chemical Addition

For the continuous system, sulfur dioxide is added according to the following:

(lbs SO_2/day) = (15.43) (flow to unit-MGD) Cr+6 mg/l)

In the batch mode, sodium bisulfite is added in place of sulfur dioxide according to the following:

(lbs $NaHSO_3$/day) = (20.06) (flow to unit-MGD) (Cr+6 mg/l)

.   Energy

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Two horsepower is required for chemical mixing. The mixers are assumed to operate continuously over the operation time of the treatment system.

Given the above requirements, operation and maintenance costs are calculated based on the following:

. $6.00 per manhour + 10 percent indirect labor charge
. $380/ton of sulfur dioxide
. $20/ton of sodium bisulfite
. $0.032/kilowatt hour of required electricity

In Process Treatment and Control Components

A wide variety of in-process controls have been identified for application to battery manufacturing wastewaters, and many of these require in process treatment or changes in manufacturing facilities and capital equipment for which additional costs must be estimated. For most of these, especially recirculation and reuse of specific process streams, the required equipment and resultant costs are identical to end-of-pipe components discussed above. In particular, cost estimates (Figures VIII-24 and VIII-25 (Pages 666-667) for the recirculation of rinsewater, scrubber water, seal or ejector water, and area wash water except for amalgamation areas are based on holding tank costs with sizing assumptions discussed for each system addressed, and additional costs for line segregation to cover piping changes (Figure VIII-26 (Page 668)). The recirculation of amalgamation area wash water requires the removal of mercury for which costs are estimated based on the sulfide precipitation and clarification system previously discussed. Costs for recirculation of lead-acid battery wash waters are presented in Figure VIII-27 (Page 669).

In process control techniques for which specific costs must be estimated include the use of slow-rate charging for lead-acid batteries, and the implementation of countercurrent rinses in a variety of process operations.

The use of slow charging rates for lead acid batteries eliminates the use of contact cooling water, reduces the need for wet scrubbers and battery rinsing, and is compatible with single fill operation. Its implementation requires the provision of additional floor area and charging racks to accommodate a larger inventory of batteries on-charge simultaneously. Instantaneous power demand, and therefore the size of required rectification and control equipment are unchanged.

Capital Cost. Required capital expenditures are estimated based on erection of a building to provide 0.8 square feet of floor area per pound of batteries produced per hour to allow for an increase in the

time on-charge of 6 days. This area is based on a typical density of approximately 50 lbs per square foot for the batteries themselves and a 40 percent packing density in the charging area and six high stacking of the batteries.

Building costs are shown as a function of lead used in Figure VIII-28 (Page 670). Twenty percent is included in these costs to allow for installation of charging racks and necessary services. Annual costs of capital for the building are estimated based on a 25 year capital recovery rather than the 10 year period used for waste treatment equipment. This is consistent with normal accounting practices.

Operation and Maintenance. Required handling of batteries and electric power requirements are not affected by this process change. Further, batteries on slow-rate charge require minimal attention. Therefore, no operating and maintenance costs are calculated for this in process control technique.

Countercurrent rinsing requires additional rinse tanks or spray equipment and plumbing as compared to single stage rinses, and extension of materials handling equipment or provision of additional manpower for rinse operation.

Summary of Treatment and Control Component Costs. Costs for each of the treatment and control components discussed above as applied to process wastewater streams within the battery manufacturing category are presented in Tables VIII-8 through VIII-19 (Pages 684- 695). Three levels of cost are provided for each technology representative of typical, low, and high raw waste flow rates encountered within the category.

TREATMENT SYSTEM COST ESTIMATES

Estimates of the total cost of wastewater treatment and control systems for battery manufacturing process wastewater are made by incorporating the treatment and control components discussed above. Cost estimates representing three different flow rates corresponding to median (typical), low and high flow rates in the subcategory addressed are presented for each system in order to provide an indication of the range of costs to be incurred in implementing each level of treatment. Since some plants in each subcategory report zero wastewater discharge, and will therefore incur zero treatment and control costs, low flow rates used in cost estimation represent low flow values at plants reporting wastewater and are not true minima for the subcategory. All available flow data from industry data collection portfolios were used in defining median, maximum and minimum raw waste flows, and flow breakdowns where streams are segregated for treatment, for use in these cost estimates. Raw waste

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characteristics were determined based on sampling data as discussed in Section V.

The system costs presented include component costs as discussed above and subsidiary costs including engineering, line segregation, administration, and interest expense during construction. In each case, it is assumed that none of the specified treatment and control measures are in place so that the presented costs represent total costs for the systems.

BPT System Cost Estimates

Cadmium-Subcategory - The BPT treatment system for this subcategory, shown in Figure IX-1 (Page 738), consists of lime precipitation and clarification of all process wastewater for the removal of nickel, cadmium and other toxic metals, and includes a vacuum filter for dewatering the clarifier sludge. Rationale for selection of this system is presented in Section IX.

Assumptions used in sizing system components are those discussed for the individual treatment components. Estimates of costs for implementation of BPT treatment and control for this subcategory are presented in Table VIII-20 (Page 696·).

Data from dcps and visits were evaluated to determine what kinds of in-process treatment existed for wastewater conservation and what kinds of loadings had been achieved or were achievable. These technologies include control of water fluctuations by adequate instrumentation, reuse of water in another process, countercurrent rinsing and in-line treatment followed by water reuse. A summary of investment and annual costs for in-process control technologies as identified in Sections IX and X are provided in Figures VIII-29 and VIII-30 (Pages 671-672) for all treatment levels for all eight plants considered. BPT in-process costs reflect additional controls required for water use reduction at high flow plants.

Calcium Subcategory - The BPT treatment system, shown in Figure IX-2 (Page 739), consists of the treatment of two streams. The first waste stream is settled to remove asbestos, barium chromate and suspended zirconium powder, reduced to insure that no slightly soluble barium chromate provides hexavalent chrome, and then merged with the second stream. The combined stream, treated with lime to remove various dissolved metals is settled and skimmed in the same clarification system to remove residual oil and grease, and discharged. Resultant cost estimates are provided in Table VIII-21 (Page 697).

Lead Subcategory - The BPT treatment and control system for the lead subcategory is shown in Figure IX-3 (Page 740). It includes segregation of process wastewater resulting from paste application,

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multi-stage settling of this waste stream, and subsequent reuse of both the water and the settled solids in the pasting operation. For the balance of the process wastewater, lime precipitation and clarification is provided for the removal of lead and other metals. Vacuum filtration for dewatering clarifier sludge is included.

Each of the settling tanks used for pasting wastewater recirculation is sized to provide one hour of retention. Assumptions used in costing other system components are those presented in the individual technology discussions. System cost estimates include an allowance for segregating paste application wastewater as described under "Line Segregation". Resultant cost estimates are presented in Table VIII-22 (Page 698). In-process investment and annual costs are provided in Figures VIII-31 and VIII-32 (Pages 673 and 674).

Leclanche Subcategory - BPT for this subcategory achieves zero discharge of process wastewater pollutants by the application of in-process control techniques. No costs are incurred in achieving BPT at most plants in the subcategory because no process wastewater is presently produced. Cost estimates for the remaining facilities reflect holding tanks, pumps, piping, and treatment facilities needed to achieve recycle of process wastewater from paste setting and from equipment and tool washing operations. Paste setting wastewater is treated by sulfide precipitation (using ferrous sulfide) prior to recycle, and equipment wash wastewater is treated in settling tanks. In some cases, where the reported volume of process wastewater was small, estimated costs reflect contract removal of the wastes rather than treatment and recycle. Resultant cost estimates are summarized in Table VIII-23 (Page 699).

Lithium Subcategory - BPT treatment for this subcategory Figure IX-4 (Page 741) includes grouping wastes into three possible streams. The first stream resulting from the cathode system of the cell may contain thionyl chloride and sulfur dioxide. It is aerated to reduce oxygen demand neutralized to form harmless products, settled and discharged. The second stream associated with heat paper manufacture is settled to remove asbestos, barium chromate, and zirconium powder suspension and reduced to insure that any chromate is in the trivalent state. This stream is merged with remaining wastes which are treated by lime and settled in a clarifier containing a skimmer for removal of residual oil and grease. Resultant metallic sludges are passed to a vacuum filter and the treated water is discharged. Typical costs for the system are provided by Table VIII-24 (Page 700). Rationale for selection of the BPT system as well as the basis for determination of flow rates and raw waste characteristics are discussed in Section IX.

Magnesium Subcategory - The BPT treatment for this subcategory presented in Figure IX-5 (Page 742) includes grouping wastes into four possible streams. Wastes from etching glass beads used as battery

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separators are treated with lime to precipitate calcium fluoride, aerated to remove ammonia, and then blended with other waste streams for further treatment. Water containing silver chloride and photo development chemicals is also aerated with the preceding waste to reduce oxygen demand before being joined with other waste streams. Water associated with heat paper manufacture is settled to remove asbestos, barium chromate and zirconium and reduced to insure any chromate remaining is in the trivalent state before joining with other waste streams. Miscellaneous wastes are blended with wastes resulting from the above treatment and treated with lime and settled to remove trivalent chromium, metals, and suspended solids. The clarifier may incorporate oil skimming for the removal of residual oils. All precipitates are dewatered by vacuum filtration. Representative treatment costs are presented in Table VIII-25 (Page 701). Rationale for selection of the BPT system as well as the basis for the determination of flow rates and raw waste characteristics are discussed in Section IX.

Zinc Subcategory - The BPT wastewater treatment and control system for this subcategory includes sulfide precipitation, clarification, and filtration as shown in Figure IX-6 (Page 743). In-process controls included in BPT are limited to water use controls widely demonstrated in present practice, and the use of water-efficient techniques for general plant floor cleaning. Data from DCPs and plant visits were evaluated to determine the effects of in-process technology on individual process loadings. Adequate instrumentation to control water use fluctuations was included in BPT costs. Holding tanks, water reuse, countercurrent rinsing, and in lime treatment followed by reuse are all successfully practiced and were costed for various treatment levels. For BAT-2 in-line sulfide precipitation and settling for wet amalgamation and treatment of process solutions and rinses by reverse osmosis for reuse in divalent silver production were costed. A summary of investment and annual costs are provided in Figures VIII-33 and VIII-34 (Pages 675 and 676) respectively for the thirteen plants considered.

BPT cost estimates are presented in Table VIII-26.

The assumptions in costing end-of-pipe treatment components are those discussed for the individual technologies. Wastewater flow rates represented in Table VIII-26 span the range encountered in data collection portfolios from plants in this subcategory (except for zero discharge facilities). Raw waste characteristics used in cost estimation correspond to a representative mix of waste streams derived from plant visit data. Rationale for selection of the BPT system is discussed in Section IX.

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BAT Treatment System Cost Estimates

Cadmium Subcategory - Costs are provided for three alternative levels of treatment and control considered appropriate for BAT.

BAT Option 1

As shown in Figure X-1 (Page 766), end-of-pipe treatment includes sulfide precipitation and clarification. A vacuum filter is provided for dewatering clarifier sludge. In addition, a number of in-process control techniques are included to limit the volume of process wastewater and pollutant loads to treatment. These include recirculation of wet scrubber solutions, control of rinse flow rates, and use of dry brushing for removal of excess material from impregnated anodes and cathodes.

Costs for recirculation of scrubber solutions are based on the provision of tanks providing 2 hours retention of the scrubber discharge. No costs are determined for control of rinse flow rates since this can be accomplished with minimum manpower and manual flow control values which are present on most units or available at low cost. Similarly, no costs were estimated for the use of dry brushing processes since these are observed to be used in existing facilities on a competitive basis with wet brushing techniques. Cost estimates also include costs for the segregation of two scrubber discharge streams. Assumptions in costing end-of-pipe treatment components are those discussed for the individual technologies. Resultant cost estimates are presented in Table VIII-27 (Page 703). In-process costs are presented in Figures VIII-29 and VIII-30 (Pages 671 and 672).

BAT Option 2

End-of-pipe treatment provided for cadmium subcategory wastes at BAT Option 2 is identical to that provided at BAT Option 1. In-process control techniques include those recommended for BAT Option 1 plus the use of multistage countercurrent rinses after electrode deposition impregnation and formation, and the reuse of final product wash water after cadmium powder precipitation.

Cost estimation for multistage countercurrent rinses are based on present rinse flow and production rates and considerations previously discussed for this in-process technique. Costs for reuse of final product wash water after cadmium powder precipitation are based on provision of a tank for retention of final wash water from one batch of product for use in early rinses of the next batch. Table X-2 (Page 767) shows total BAT Option 2 system cost estimates. In-process costs are presented in Figures VIII-29 and VIII-30 (Pages 671 and 672). Resultant cost estimates are in Table VIII-28 (Page 704).

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. BAT Option 3

End of pipe treatment for BAT Option 3 includes concentration of
process wastewater using reverse osmosis prior to treatment identical
to that provided at BAT Option 2. Permeate from the reverse osmosis
unit is reused in the process. As shown in Figure X-3 (Page 768),
wastewater is treated by neutralization and filtration prior to
reverse osmosis to protect the permeators. In process control
techniques at BAT Option 3 include formation of electrodes in the
battery case without subsequent rinsing, and improved process control
on cadmium powder precipitation to eliminate the need for rework of
this product in addition to the in-process controls discussed as BAT
Option 2.

No costs are estimated for the additional BAT Option 3 in-process
control techniques. Total system costs are presented in Table VIII-29
(Page 70b).

. BAT Option 4

Costs for BAT Option 4 presented in Figure X-4 (Page 769) have not
been evaluated and will be included in the proposed development
document.

Calcium Subcategory - Costs are provided for two alternative levels of
treatment and control considered appropriate for BAT.

. BAT Option 1

At BAT Option 1, end-of-pipe treatment is identical to that provided
for BPT except the discharge from the BPT system is passed through a
multi-media filter prior to discharge. This filter is intended to act
as on polishing unit on the treated waste stream. The filter backwash
is returned to the treatment system. A schematic of the system is
provided in Figure X-5 (Page 770). Representative costs for this
level of treatment are provided by Table VIII-30 (Page 706).

. BAT Option 2

This level of treatment is similar to BAT Option 1 except that waste
stream 1 from heat paper production is recycled back to the process.
A schematic of the system is provided in Figure X-6 (Page 771).
Representative summary costs for this level of treatment are provided
by Table VIII-31 (Page 707).

Lead Subcategory - Costs are provided for four alternative levels of
treatment and control considered appropriate for BAT.

. BAT Option 1

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As BAT Option 1, end-of-pipe treatment is identical to that provided for BPT, but additional in-process control techniques significantly reduce the volume of wastewater which is treated and discharged. In process controls included in BAT Option 1 include:

.   elimination of wastewater discharges from formation of formation of wet and damp batteries.

.   elimination of wastewater discharges from battery rinses

.   reduction of wastewater discharges from battery wash

.   reduction of wastewater discharge from formation and dehydration of plates for dehydrated batteries.

.   recirculation of paste preparation and application wastewater as specified for BPT

Cost estimates for in process controls include paste recirculation costs included at BPT, costs for additional plant floor space to allow low rate charging of batteries, and tanks for retention of 2 hours flow from wet scrubbers on formation operations to allow recirculation and eventual use of the scrubber bleed in acid cutting. Recirculation tanks providing one hour retention to allow reuse of battery rinse water and eventual use of the discharge in acid cutting, tanks providing for retention and reuse of wastewater from vacuum ejectors or vacuum pump seals, and countercurrent rinses for dry charged electrodes are also included in cost estimates. Additional in-process control techniques applicable as BAT Option 1 for which no specific costs are estimated or which are alternatives to the control techniques chosen as a basis for cost estimates, are discussed in Sections VII and X. A schematic of the system is provided in Figure X-7 (Page 772). Total costs for implementation of this level of control and treatment are presented in Table VIII-32 (Page 708).

.   BAT Option 2

This level of treatment and control involves replacement of lime precipitation as included in BAT Level 1 with sulfide precipitation and clarification as shown in Figure X-8 (Page 773). In-process control techniques are identical to those included at BAT Option 1.

Assumptions in costing the end-of-pipe treatment components are those discussed for the individual technologies. In-process control costs are determined as for BAT Option 1. Total system costs are presented in Table VIII-33 (Page 709).

.   BAT Option 3

As shown in Figure X-9 (Page 774), the end-of-pipe treatment system provided for this level of treatment and control is equivalent to that provided for BAT Option 2 plus the provision of membrane filtration to polish the effluent from sulfide precipitationclarification treatment. In-process controls as specified for BAT Option 2 are augmented to provide for the use of recirculated treated process wastewater in rinsing open formation cathodes.

Cost estimates for this additional in-process control technique are based on the calculation of line segregation costs as previously presented to provide an estimate of typical costs of return piping from waste treatment to positive plate rinsing. Total system costs are presented in Table VIII-34 (Page 710).

. BAT Option 4

In-process control techniques included at BAT Option 4 are identical to those at BAT Option 3 but, as shown in Figure X-10 (Page 775), end of pipe treatment is significantly changed. Process wastewater is concentrated by reverse osmosis to reduce its volume prior to treatment in the BAT Option 3 system. Permeate from the RO unit is returned for process use, especially in dehydrated plate anode rinsing where high quality water is required. Prior to reverse osmosis treatment, the waste stream is pH adjusted and filtered to protect the permeation modules.

Assumptions in costing end-of-pipe treatment components are those presented in individual technology discussions. In-process control costs are identical to those estimated for BAT Option 3. Total system costs are presented in Table VIII-35 (Page 711).

Leclanche Subcategory - Only one option is considered for BAT for this subcategory. This option is identical to BPT and achieves zero discharge of process wastewater pollutants by the application of in-pcess control technology. Cost estimates for the implementation of this technology at Leclanche subcategory plants are presented in Table VIII-3.3.

Lithium Subcategory - Cost estimates are provided for three alternative levels of treatment and control presented for evaluation as BAT.

. BAT Option 1

This level of treatment is similar to that prescribed for BPT except that discharge from settling is passed through a multimedia polishing filter. The schematic for this system is provided in Figure X-11 (Page 776). The filter backwash is returned to waste treatment. Costs are provided in Table VIII-36 (Page 712).

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.   BAT Option 2

At this level of treatment and control (Figure X-12 (Page 777)), BAT
Level 1 treatment is supplemented by 100 percent recycle of the heat
paper waste stream and chemical reduction is consequently eliminated.
Costs are provided in Table VIII-37 (Page 713).

.   BAT Option 3

At this level of treatment and control (Figure X-13 (Page 778)),
treatment identical to BAT Option 2 is provided, all of the wastewater
from SO_2 or thionyl chloride handling is recycled for process use
after treatment. Costs are identical to those for BAT Option 2 as
shown in Table VIII-37.

Magnesium Subcategory - Cost estimates are provided for three
alternative levels of treatment and control presented for evaluation
as BAT.

.   BAT Option 1

This level of treatment is similar to that prescribed for BPT except
that effluent from the BPT system is passed through a polishing
filter. The schematic for this system is provided in Figure X-14
(Page 779). Costs are provided in Table VIII-38 (Page 714).

.   BAT Option 2

At this level of treatment (Figure X-15 (Page 780)) and control the
treatment of BAT Option 1 is supplemented by recycle of 100 percent of
the heat paper waste stream to the process, and chrome reduction is
eliminated. Costs are provided in Table VIII-39 (Page 715).

.   BAT Option 3

This level of treatment is similar to that prescribed for BAT Option 2
except that photographic chemicals associated with the silver chloride
stream are separated from the effluent by a carbon adsorption system
prior to further treatment. A schematic is provided by Figure X-16
(Page 781) and costs are presented in Table VIII-40 (Page 716).

Zinc Subcategory - Cost estimates are provided for three alternative
levels of treatment and control presented for evaluation as BAT.

.   BAT Option 1

This level of treatment and control combines end-of-pipe treatment as
specified for BPT with additional in-process control techniques to
reduce wastewater flow rates and pollutant loads discharged to

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treatment. In process controls include countercurrent rinsing of amalgamated zinc, treatment and reuse of amalgamation area clean up, reductions in rinse flow rates by using multi-stage and countercurrent rinses on a variety of process operations, and use of dry clean-up techniques for general plant floor areas. The schematic for the system is shown in Figure X-17 (Page 782).

Cost estimates include provision of eight tanks, associated pumps and piping to provide retention of rinse waters from wet amalgamation operations allowing countercurrent rinsing in which water is used in an earlier rinse stage on each batch of amalgam produced, and water from only the first rinse is discharged to treatment. Treatment and recycle costs for amalgamation area wash water are based on batch treatment using ferrous sulfide and are discussed under sulfide precipitation-clarification. Cost estimates are also provided for countercurrent rinses as described in the general discussion of that technology. No costs are estimated for dry clean up of general plant floor areas. Total system costs are presented in Table VIII-41 (Page 717).

.   BAT Option 2

At this level of treatment and control, end-of-pipe treatment is improved by replacement of the multimedia filter used for polishing clarified effluent in BPT and BAT Option 1 with a membrane filter as shown in Figure X-18 (Page 783). In process controls in addition to those provided in BAT Option 1 are also included. Specifically, reuse of treated wastewater for amalgamation equipment wash on wet amalgamation operations, elimination of equipment and area wash waters from other amalgamation processes, and selection of cell wash formulations to eliminate chromium and cyanide from process effluents are included.

Costs for reuse of treated wastewater for amalgamation equipment wash are estimated based on provision of pumps and piping as discussed for line segregation costs. No costs are estimated for elimination of amalgamation wastewater (from other than wet amalgamation operations) or for cell wash formulation substitution since these are observed in present practice on a competitive basis. Assumptions in costing end-of-pipe treatment components are discussed in general discussion for each of the individual technologies involved. Total system costs are presented in Table VIII-42 (Page 718).

.   BAT Option 3

This level of treatment and control provides for concentration of process wastewater by reverse osmosis prior to treatment equivalent to thin provided at BAT Option 1. As shown in Figure X-19 (Page 784) wastewater is treated by pH adjustment and filtration prior to RO.

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Permeate is recycled for use in the process. Additional in-process controls are also provided to eliminate all wastewater from amalgamation by substitution of a dry amalgamation process for wet amalgamation where it is practiced.

Since dry and wet amalgamation are observed to be competitive processes in the subcategory at present, no costs for process substitution are estimated. Assumptions in costing end-of-pipe components have been discussed in earlier sections. Total system cost estimates are presented in Table VIII-43 (Page 719).

System Cost Estimates - (New Sources)

The suggested treatment alternatives for NSPS Levels 1 through 3 are identical to the treatment alternatives for existing sources BAT Levels 1 through 3. These costs were presented in Tables VIII-20 through VIII-43 (Pages 696—719).

Pretreatment System Cost Estimates

Three alternative levels of pretreatment presented for consideration are identical to BPT and BAT Options 1 and 2 respectively. Cost estimates for these levels of treatment and control have been presented on the preceding pages. Rationale for selection of these pretreatment technologies are discussed in Section XII.

Use of Cost Estimation Results

Cost estimates presented in the tables in this section are representative of costs typically incurred in implementing treatment and control equivalent to the specified levels. They will not, in general, correspond precisely to cost experience at any individual plant. Specific plant conditions such as age, location, plant layout, or present production and treatment practices may yield costs which are either higher or lower than the presented costs. Because the costs shown are total system costs and do not assume any treatment in place, it is probable that most plants will require smaller expenditures to reach the specified levels of control from their present status.

The actual costs of installing and operating a BPT system at a particular plant may be substantially lower than the tabulated values. Reductions in investment and operating costs are possible in several areas. Design and installation costs may be reduced by using plant workers. Equipment costs may be reduced by using or modifying existing equipment instead of purchasing all new equipment. Application of an excess capacity factor, which increases the size of most equipment foundation costs could be reduced if an existing concrete pad or floor can be utilized. Equipment size requirements

may be reduced by the ease of treatment (for example, shorter retention time) of particular waste streams. Substantial reduction in both investment and operating cost may be achieved if a plant reduces its water use rate below that assumed in costing.

ENERGY AND NON-WATER QUALITY ASPECTS

Energy and non-water quality aspects of the wastewater treatment technologies described in Section VII are summarized in Tables VIII-44 and VIII-45 (Pages 720 and 721). Energy requirements are listed, the impact on environmental air and noise pollution is noted, and solid waste generation characteristics are summarized. The treatment processes are divided into two groups, wastewater treatment processes on Table VIII-44 and sludge and solids handling processes on Table VIII-45.

Energy Aspects

Energy aspects of the wastewater treatment processes are important because of the impact of energy use on our natural resources and on the economy. Electrical power and fuel requirements (coal, oil, or gas) are listed in units of kilowatt hours per ton of dry solids for sludge and solids handling. Specific energy uses are noted in the "Remarks" column.

Energy requirements are generally low, although evaporation can be an exception if no waste heat is available at the plant. Thus, if evaporation is used to avoid discharge of pollutants, the influent water rate should be minimized. For example, an upstream reverse osmosis, ion exchange, or ultrafiltration unit can drastically reduce the flow rate of wastewater to an evaporation device.

Non-Water Quality Aspects

It is important to consider the impact of each treatment process on air, noise, and radiation pollution of the environment to preclude the development of a more adverse environmental impact.

In general, none of the liquid handling processes causes air pollution. With sulfide precipitation, however, the potential exists for evolution of hydrogen sulfide, a toxic gas. Proper control of pH in treatment eliminates this problem. Incineration of sludges or solids can cause significant air pollution which must be controlled by suitable bag houses, scrubbers or stack gas precipitators as well as proper incinerator operation and maintenance. Due to their high content of volatile heavy metals, (eg. cadmium and mercury) sludges from battery manufacturing wastewater treatment are not amenable to incineration except in retorts for metals recovery. None of the wastewater treatment processes causes objectionable noise and none of

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the treatment processes has any potential for radioactive radiation hazards.

The solid waste impact of each wastewater treatment process is indicated in two columns on Table VIII-4.1 and VIII-4.2. The first column shows whether effluent solids are to be expected and, if so, the solids content in qualitative terms. The second column lists typical values of percent solids of sludge or residue.

The processes for treating the wastewaters from this category produce considerable volumes of sludges. In order to ensure long-term protection of the environment from harmful sludge constituents, special consideration of disposal sites should be made by RCRA and municipal authorities where applicable.

FIGURE VIII-1

SIMPLIFIED LOGIC DIAGRAM
SYSTEM COST ESTIMATION PROGRAM

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┌─────────────────────────────────────┐
│ INPUT                                │
│ A)  RAW WASTE DESCRIPTION            │
│ B)  SYSTEM DESCRIPTION               │
│ C)  "DECISION" PARAMETERS            │
│ D)  COST FACTORS                     │
└─────────────────────────────────────┘

┌─────────────────────────────────────┐
│ PROCESS CALCULATIONS                 │
│ A)  PERFORMANCE - POLLUTANT          │
│     PARAMETER EFFECTS                │      (NOT WITHIN
│ B)  EQUIPMENT SIZE                   │       TOLERANCE LIMITS)
│ C)  PROCESS COST                     │
└─────────────────────────────────────┘

                        (RECYCLE SYSTEMS)

┌─────────────────────────────────────┐
NON-RECYCLE │ CONVERGENCE             │
SYSTEMS     │ A)  POLLUTANT PARAMETER │
            │     TOLERANCE CHECK     │
            └─────────────────────────┘

                    (WITHIN TOLERANCE LIMITS)

┌─────────────────────────────────────┐
│ COST CALCULATIONS                    │
│ A)  SUM INDIVIDUAL PROCESS           │
│     COSTS                            │
│ B)  ADD SUBSIDIARY COSTS             │
│ C)  ADJUST TO DESIRED DOLLAR         │
│     BASE                             │
└─────────────────────────────────────┘

┌─────────────────────────────────────┐
│ OUTPUT                               │
│ A)  STREAM DESCRIPTIONS -            │
│     COMPLETE SYSTEM                  │
│ B)  INDIVIDUAL PROCESS SIZE          │
│     AND COSTS                        │
│ C)  OVERALL SYSTEM INVESTMENT        │
│     AND ANNUAL COSTS                 │
└─────────────────────────────────────┘
```

Lime   Flocculant

Raw Waste
  Flow → Chemical Addition Mixing → Clarifier → Effluent
  TSS
  Pb
  Zn
  Acidity

Filtrate ← Vacuum Filter ← (from Clarifier)

Sludge Contractor Removed

FIGURE VIII-2

SIMPLE WASTE TREATMENT SYSTEM

644

645

Cost (Dollars - Jan, 78)

Flow Rate (l/hr)

Investment

Annual
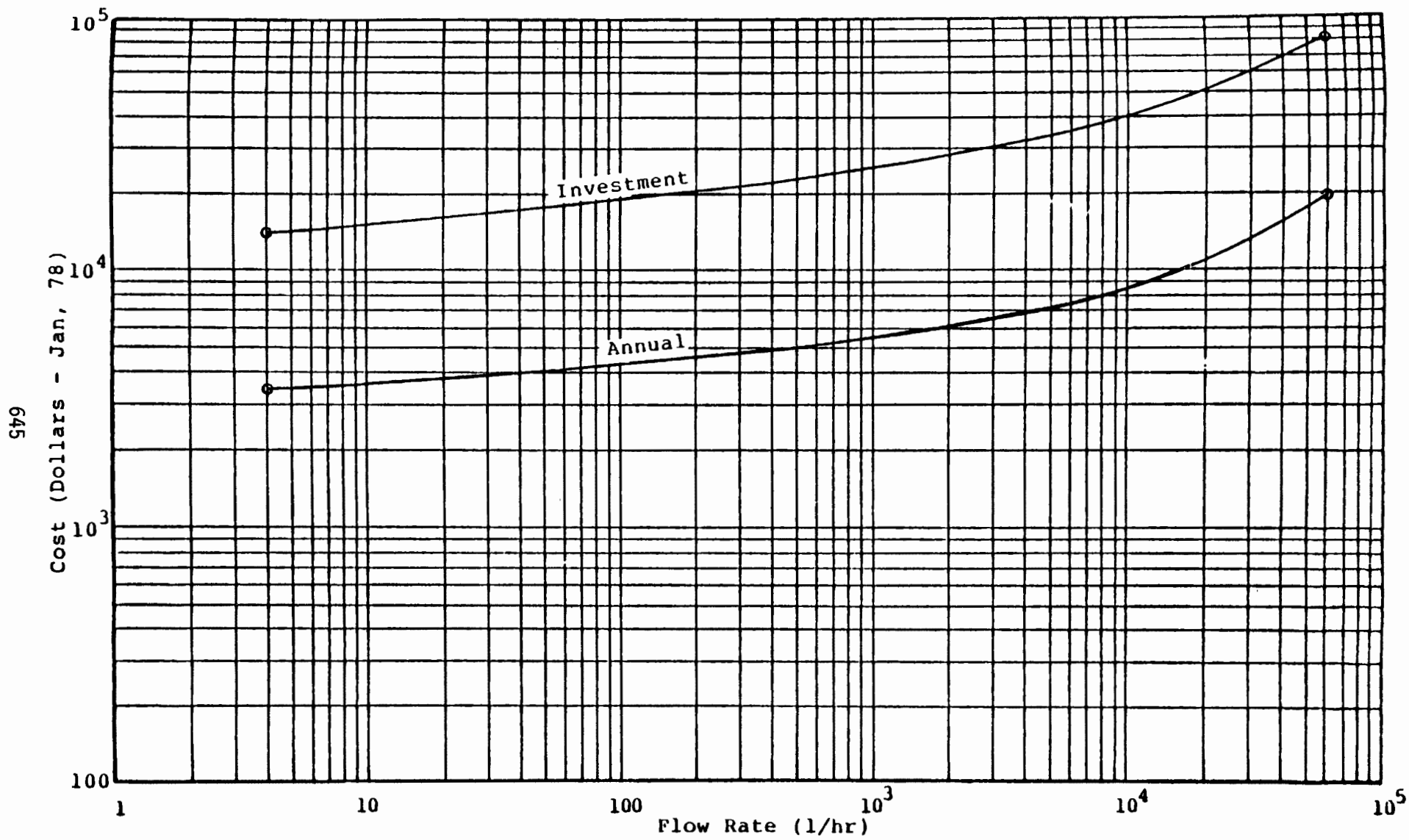
o Denotes flow limits observed for this treatment for the lead subcategory

FIGURE VIII-3

PREDICTED LIME PRECIPITATION/CLARIFICATION COSTS
CONTINUOUS
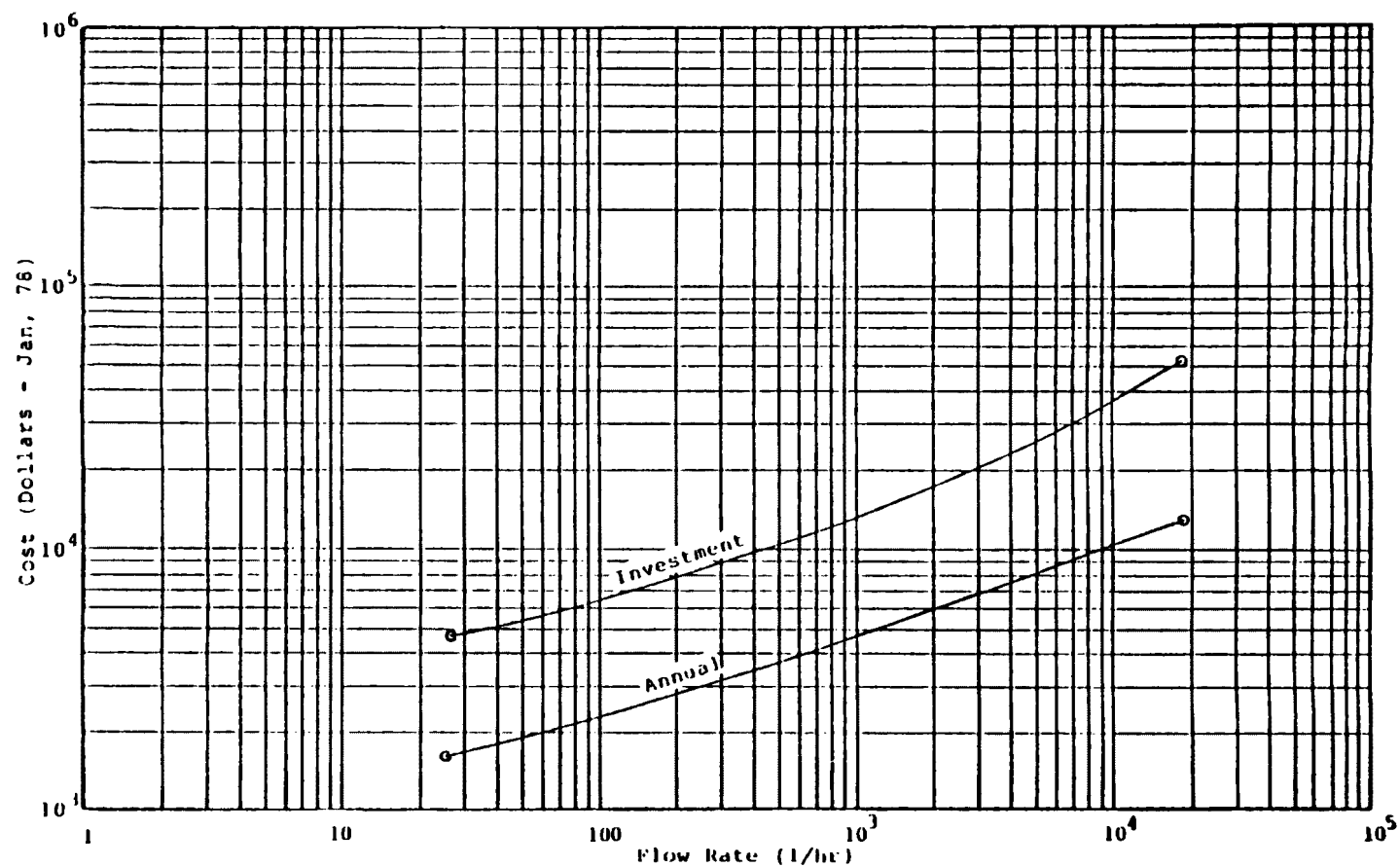
o Denotes flow limit (/ 0) observed for
this treatment in the battery
industry (non-lead subcategory).

Individual plants may differ because
of variation in operating hours.

All computer selected treatment was
batch.

FIGURE VIII-4

PREDICTED COSTS FOR PRECIPITATION/CLARIFICATION
BATCH
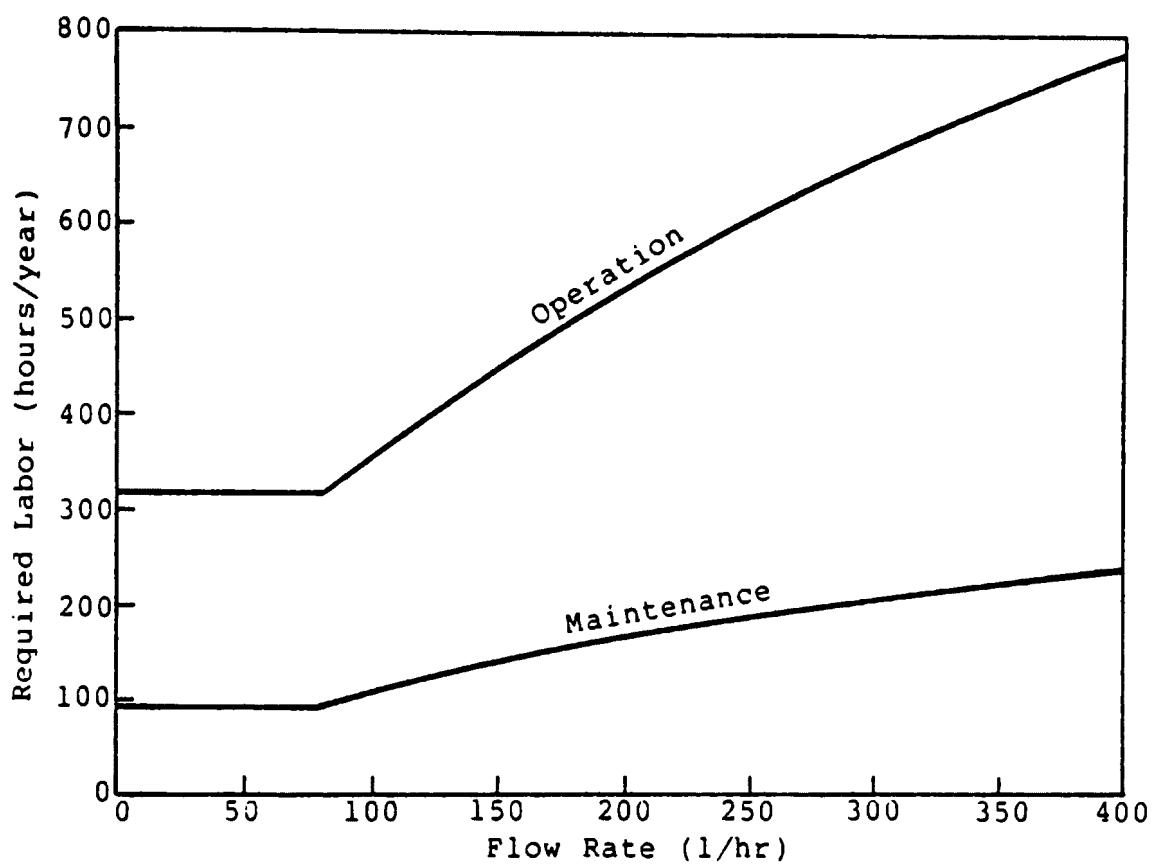
FIGURE VIII-5

CHEMICAL PRECIPITATION/CLARIFICATION COSTS
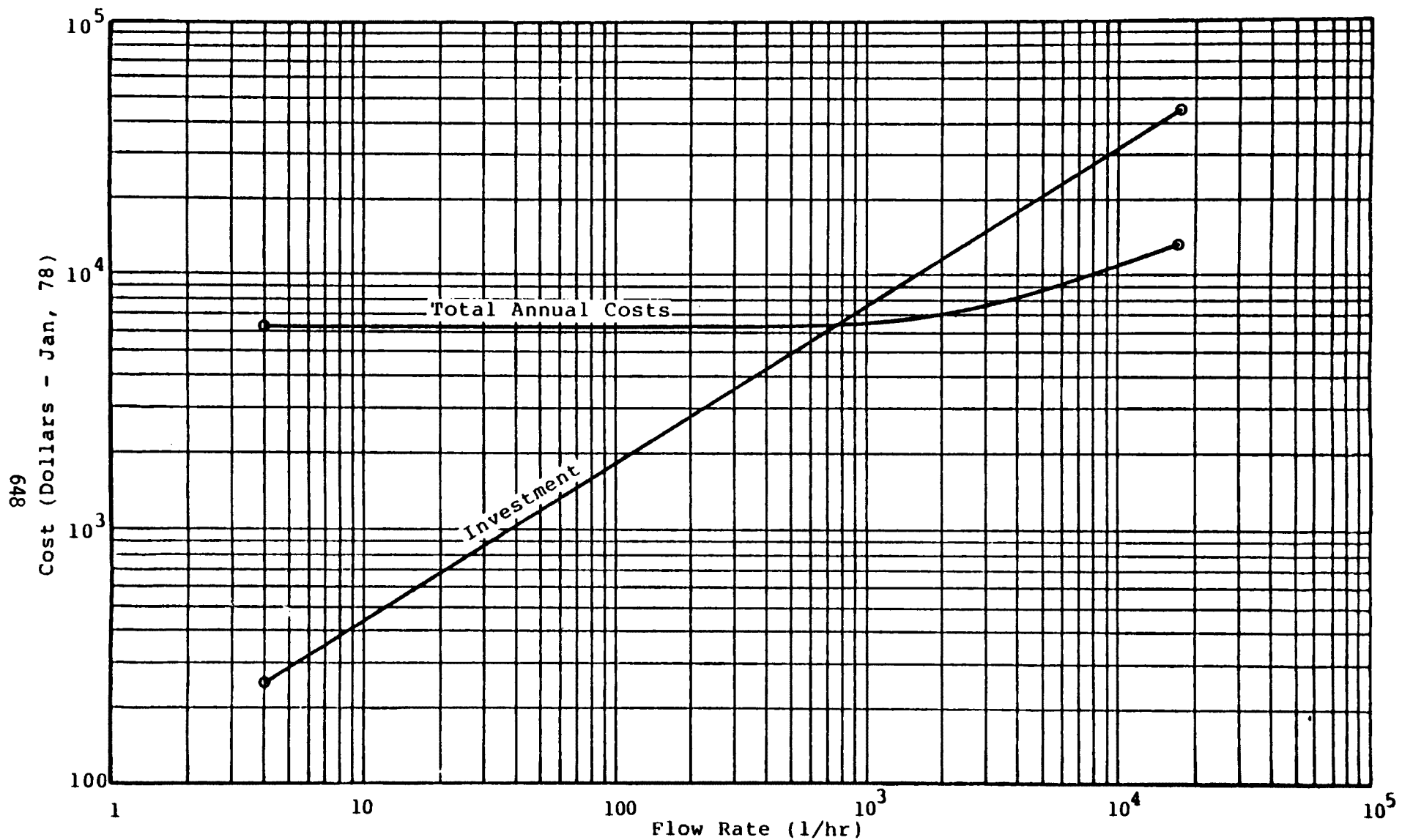
648

FIGURE VIII-6

PREDICTED COSTS OF MULTIMEDIA FILTRATION

o Denotes flow limit (≠0) observed for this treatment in the battery industry.

Individual plants may differ because of variation in operating hours.
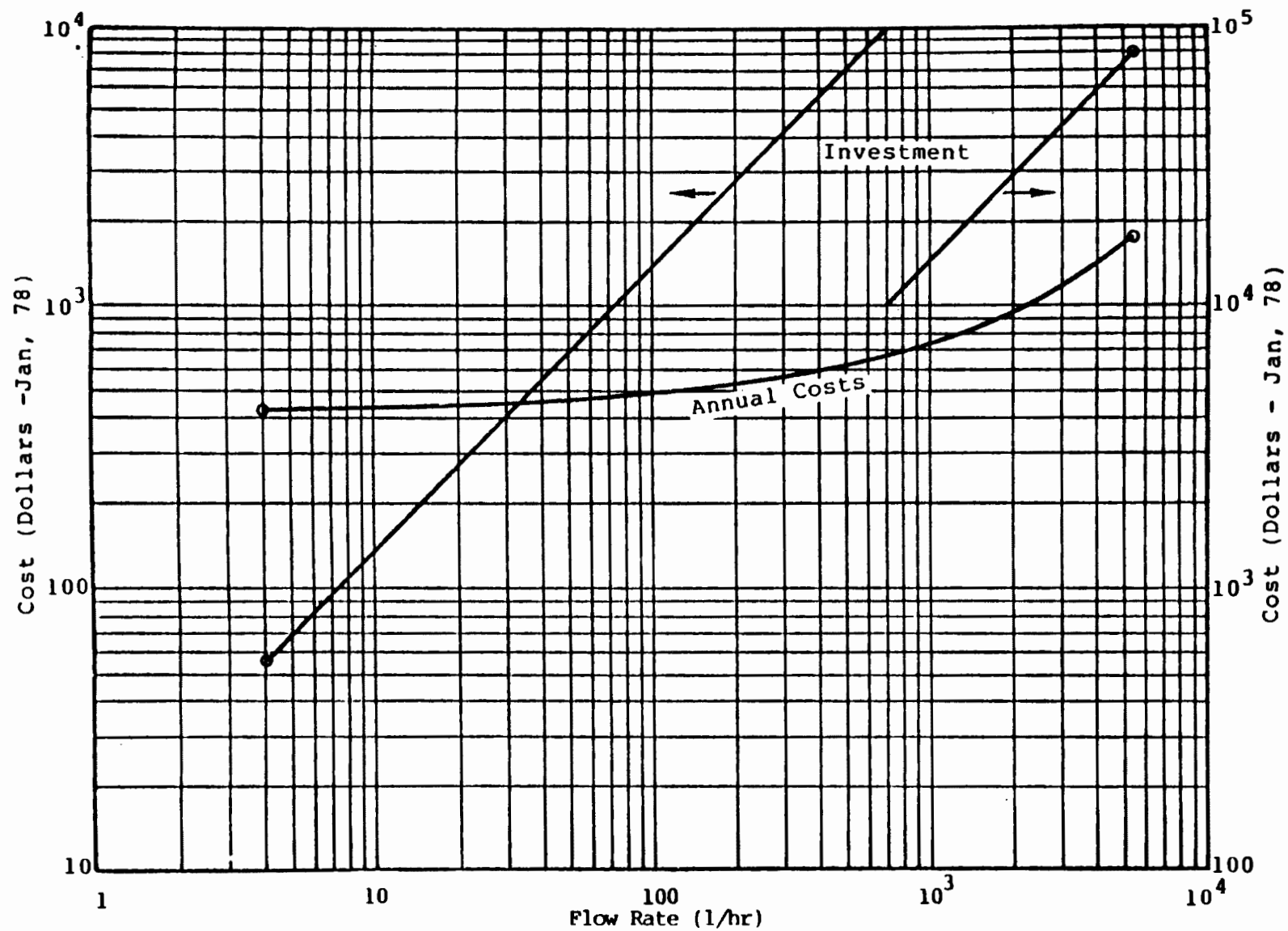
o Denotes flow limits for this treatment in the battery category.

FIGURE VIII-7

MEMBRANE FILTRATION COSTS
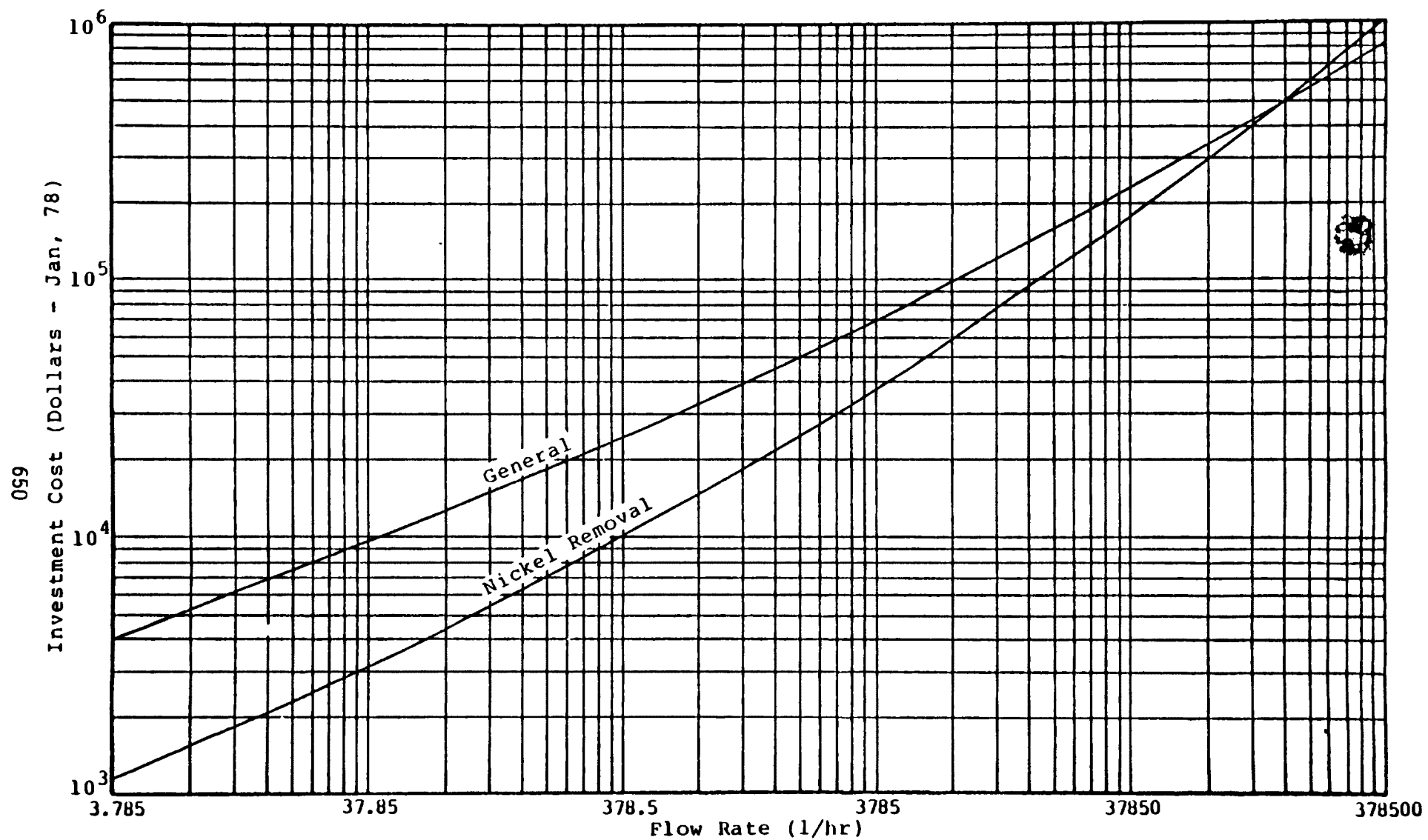
FIGURE VIII-8

REVERSE OSMOSIS INVESTMENT COSTS

651
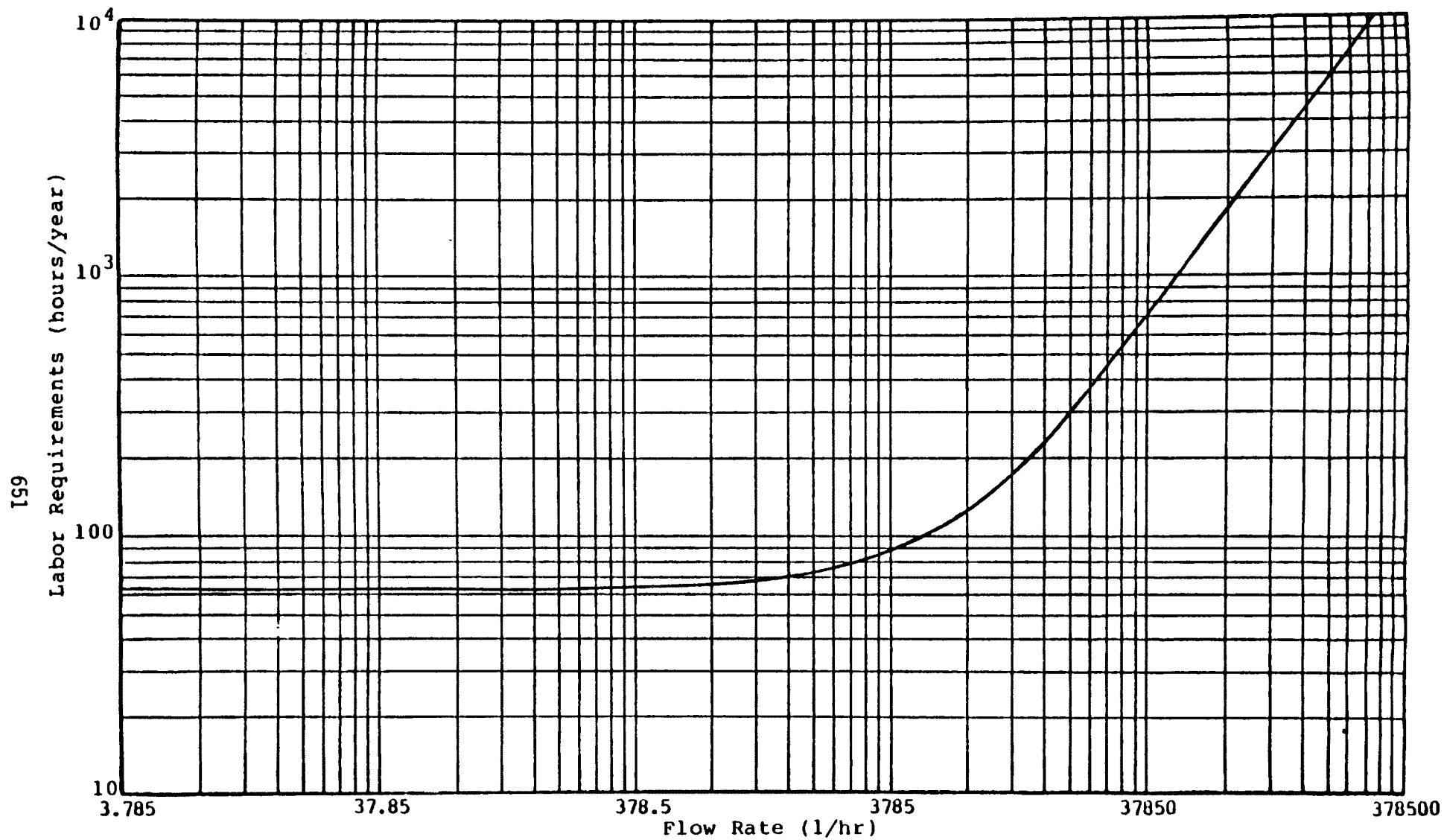
FIGURE VIII-9

REVERSE OSMOSIS LABOR REQUIREMENTS

652
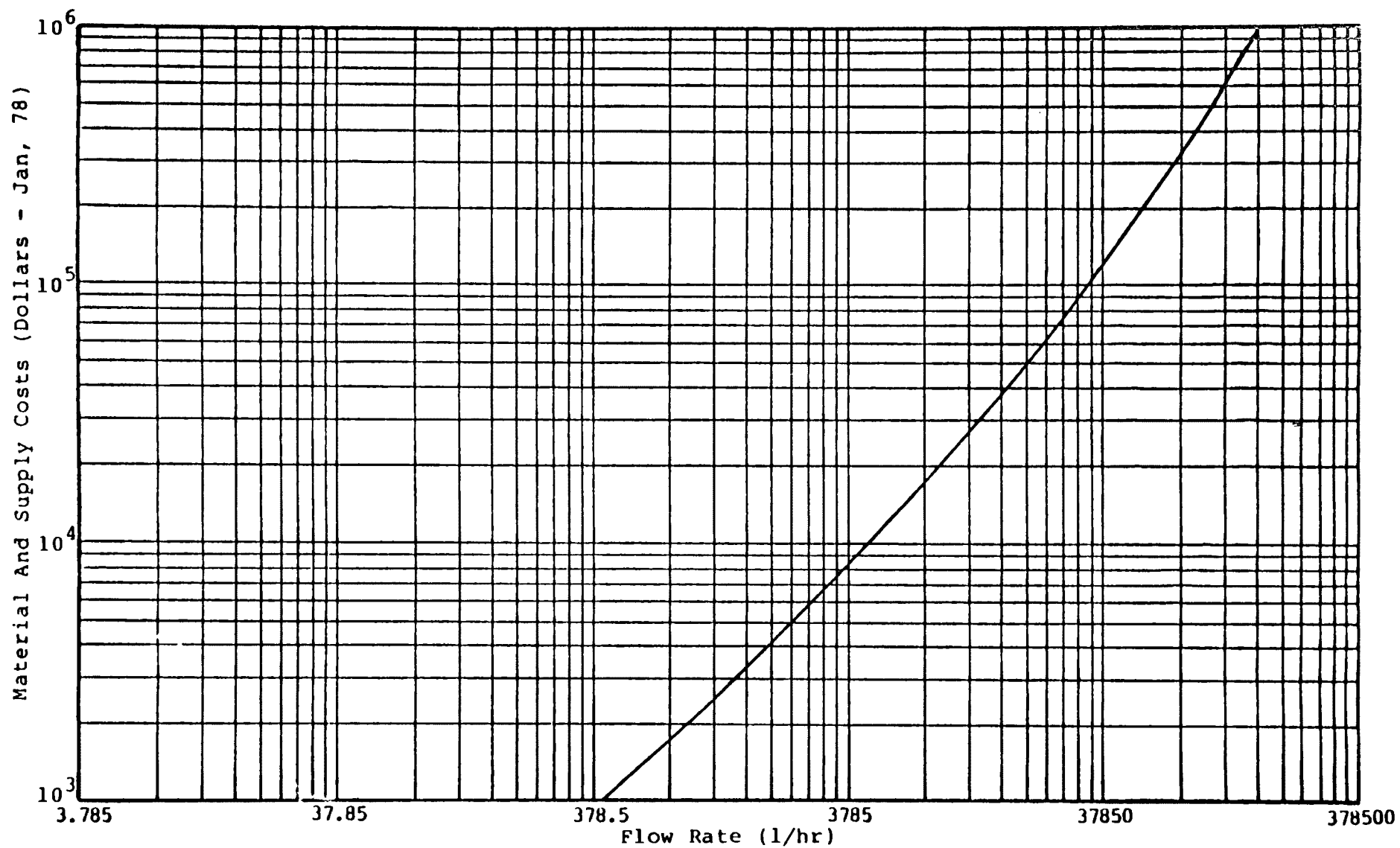
FIGURE VIII-10

REVERSE OSMOSIS MATERIAL COSTS
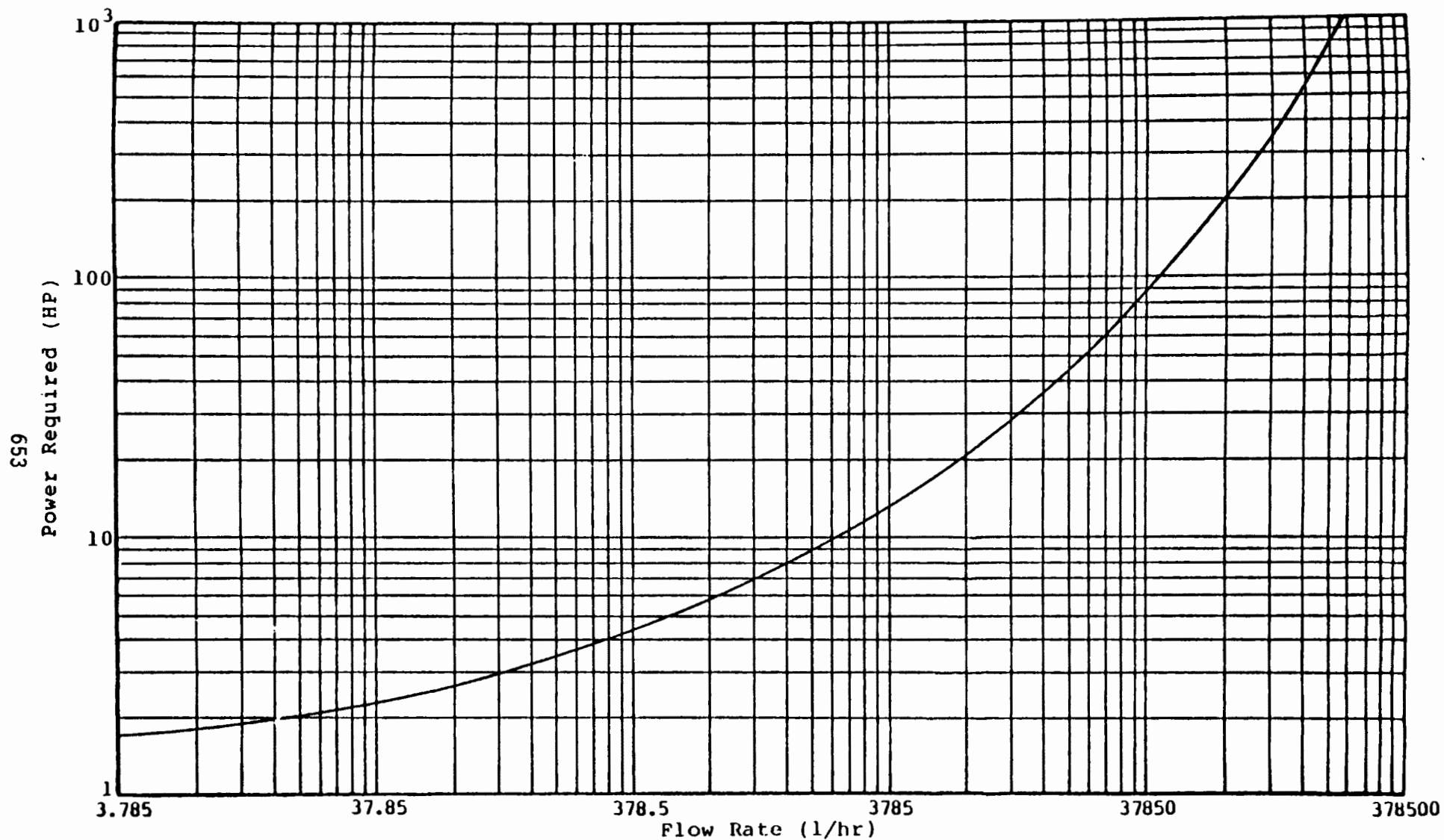
FIGURE VIII-11

REVERSE OSMOSIS POWER REQUIREMENTS

654
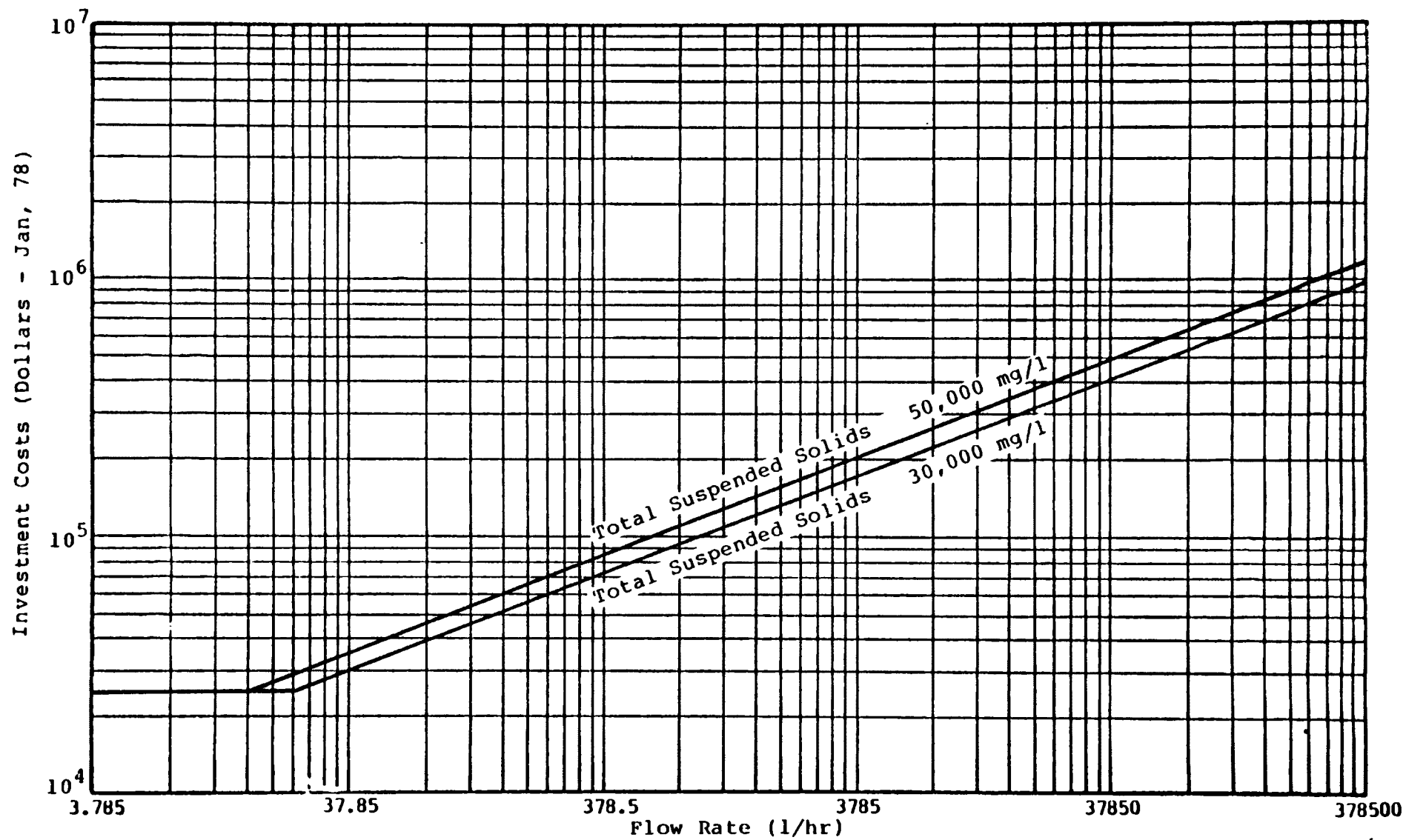
FIGURE VIII-12

VACUUM FILTRATION INVESTMENT COSTS
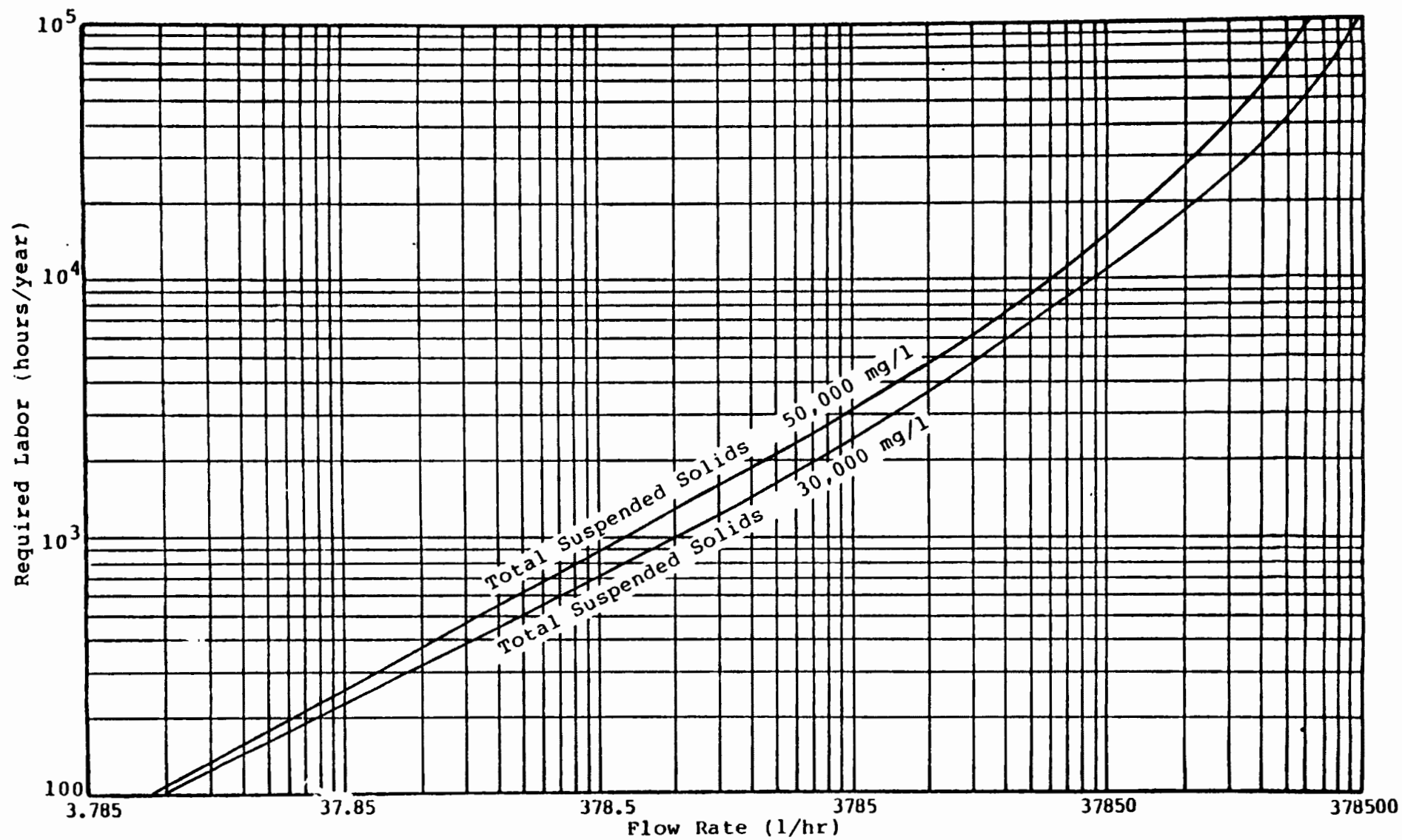
FIGURE VIII-13

VACUUM FILTRATION LABOR REQUIREMENTS

655
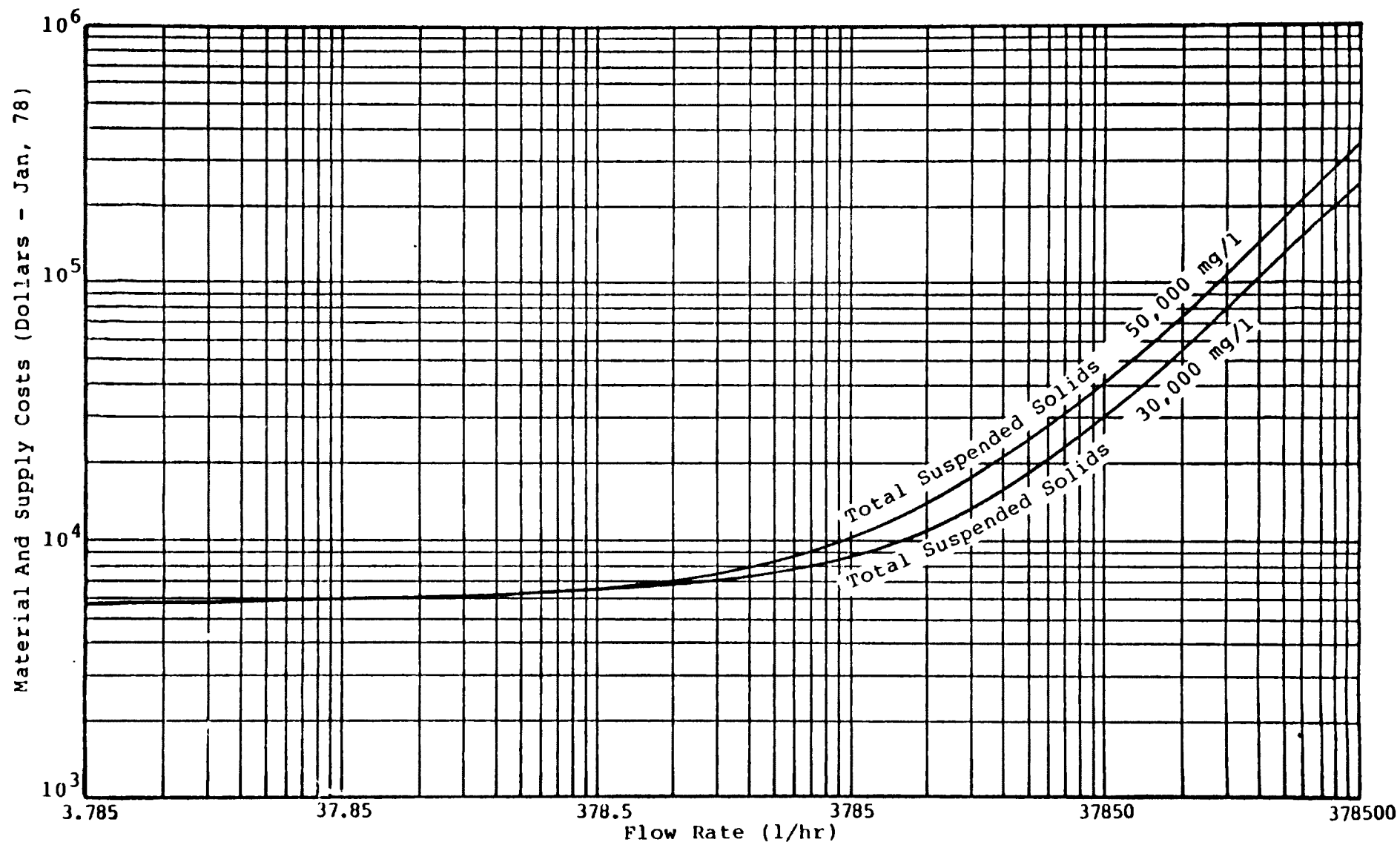
FIGURE VIII-14

VACUUM FILTRATION MATERIAL COSTS
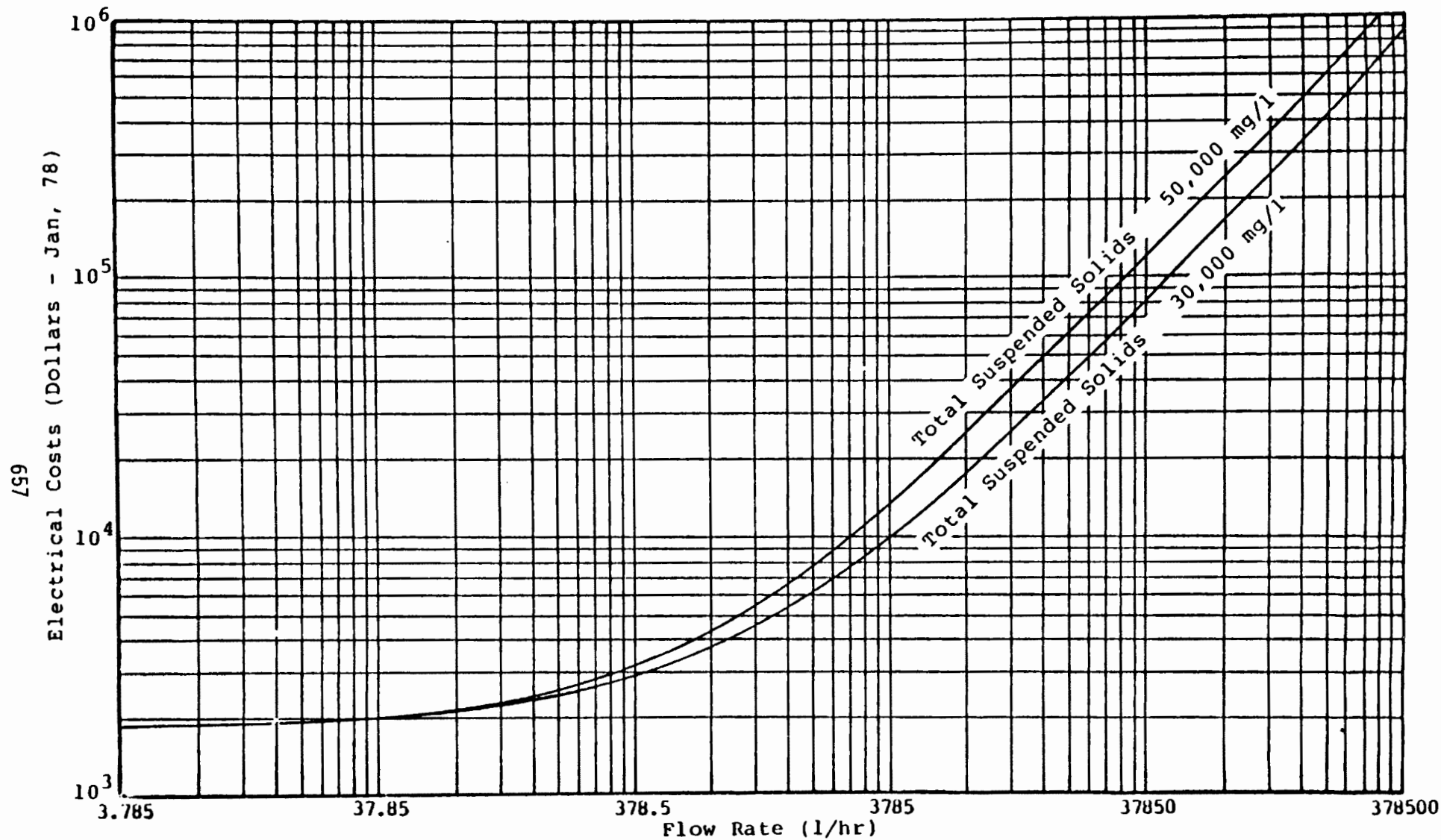
FIGURE VIII-15

VACUUM FILTRATION ELECTRIAL COSTS

FIGURE VIII-16

$$Cost = 41.93 \times Volume(liters)^{0.5344}$$

Retention Time = 12 Hours
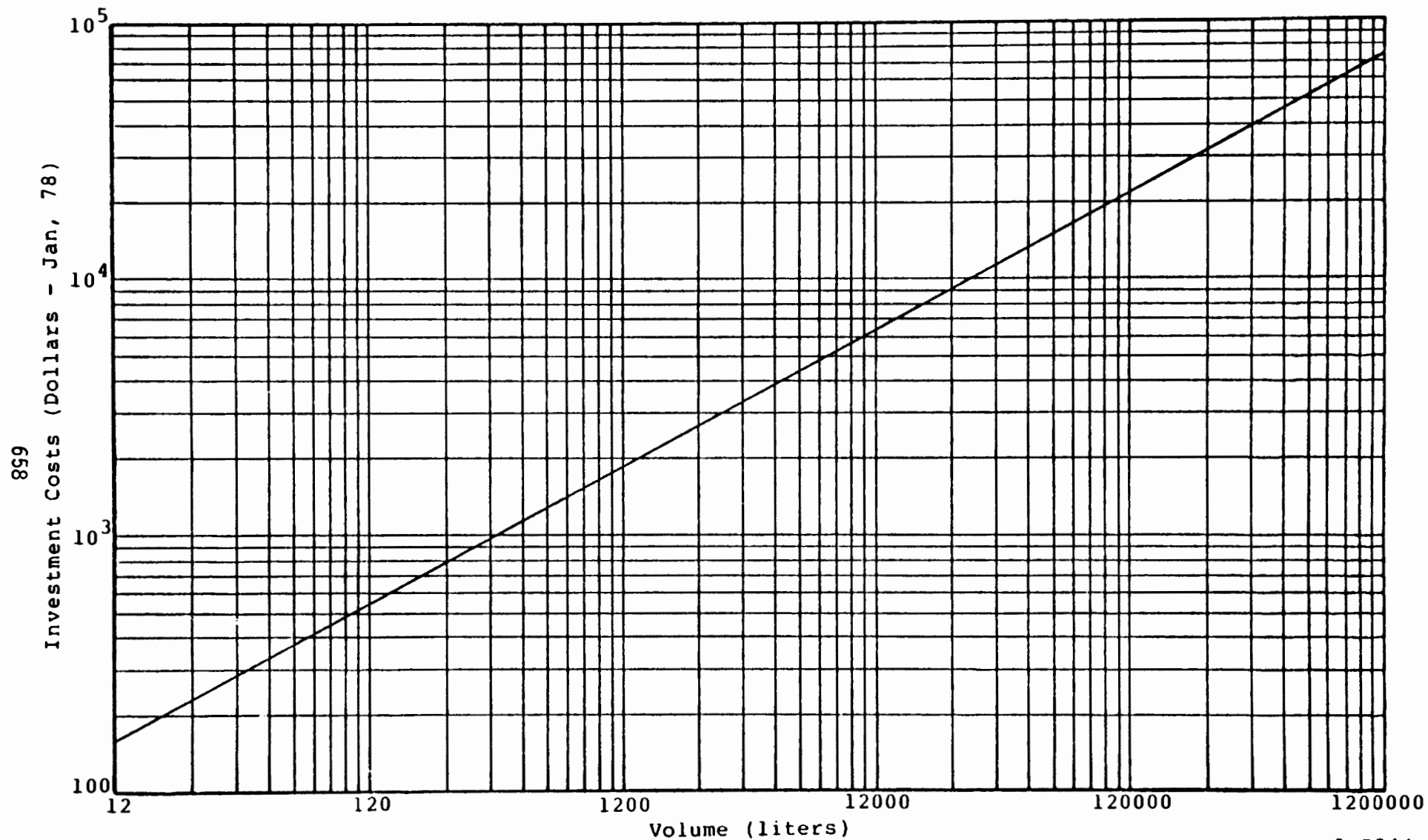
HOLDING TANK INVESTMENT COSTS
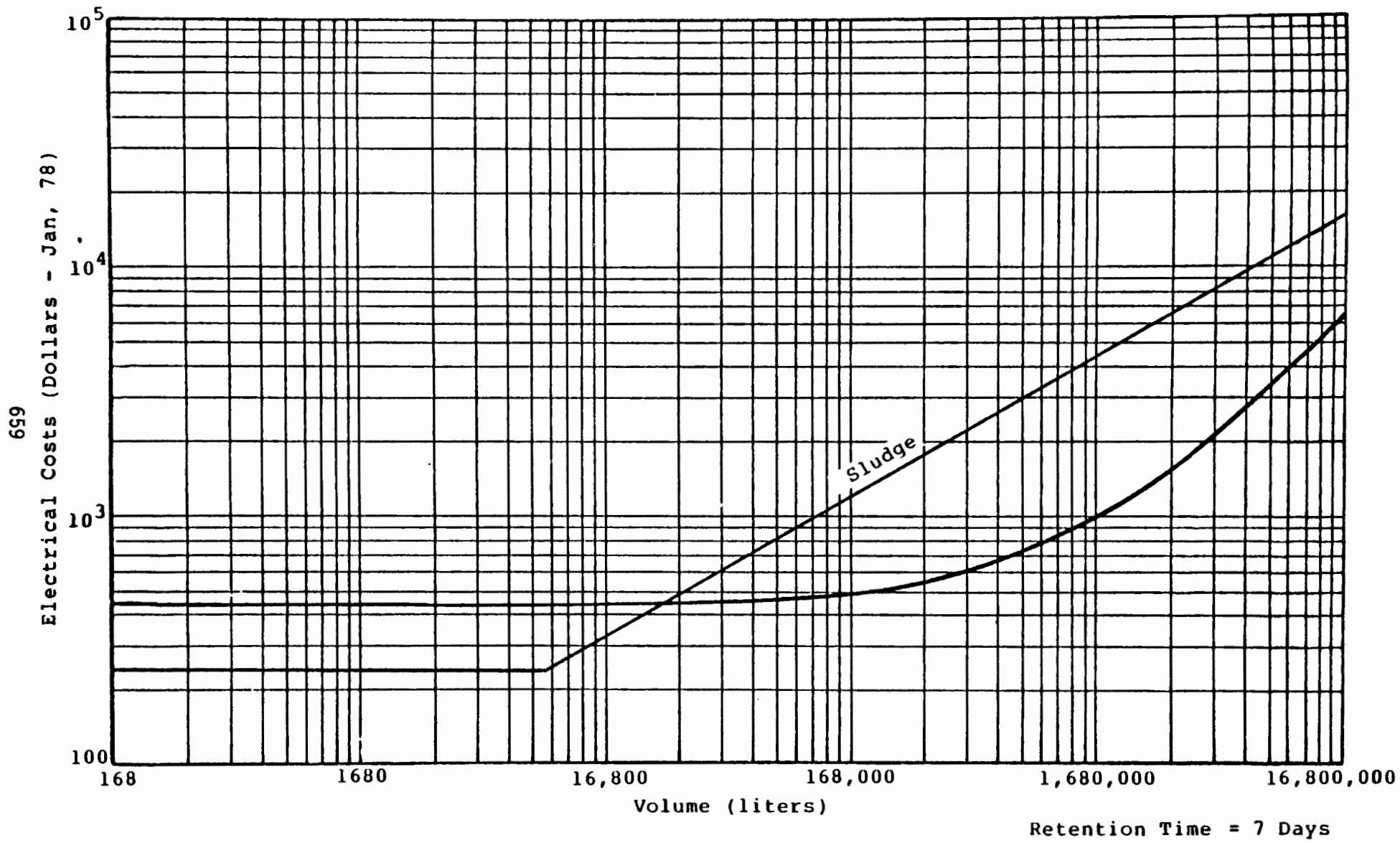
FIGURE VIII-17

HOLDING TANK ELECTRICAL COSTS
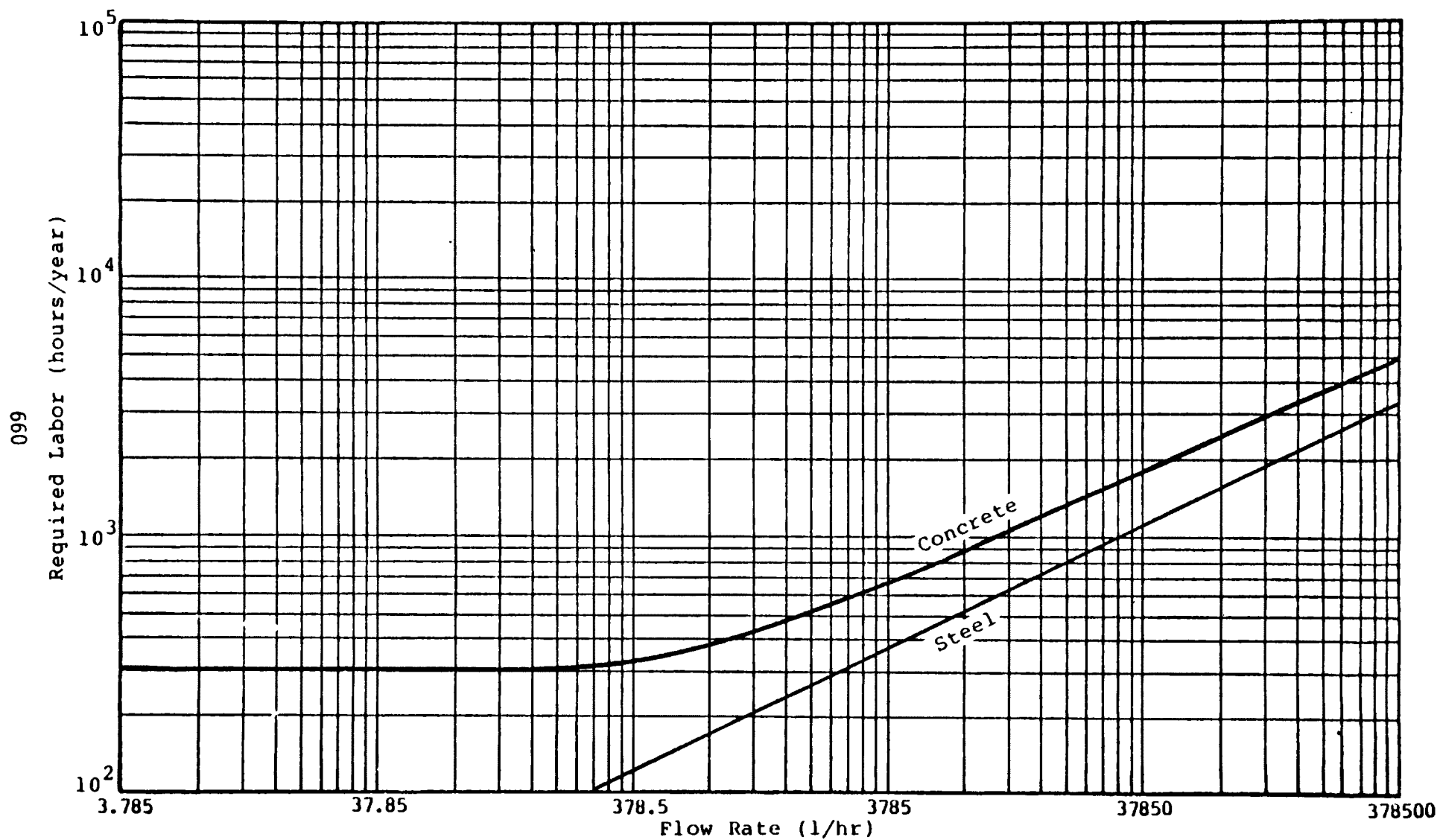
FIGURE VIII-18

HOLDING TANK LABOR REQUIREMENTS

691

FIGURE VIII-19

NEUTRALIZATION INVESTMENT COSTS
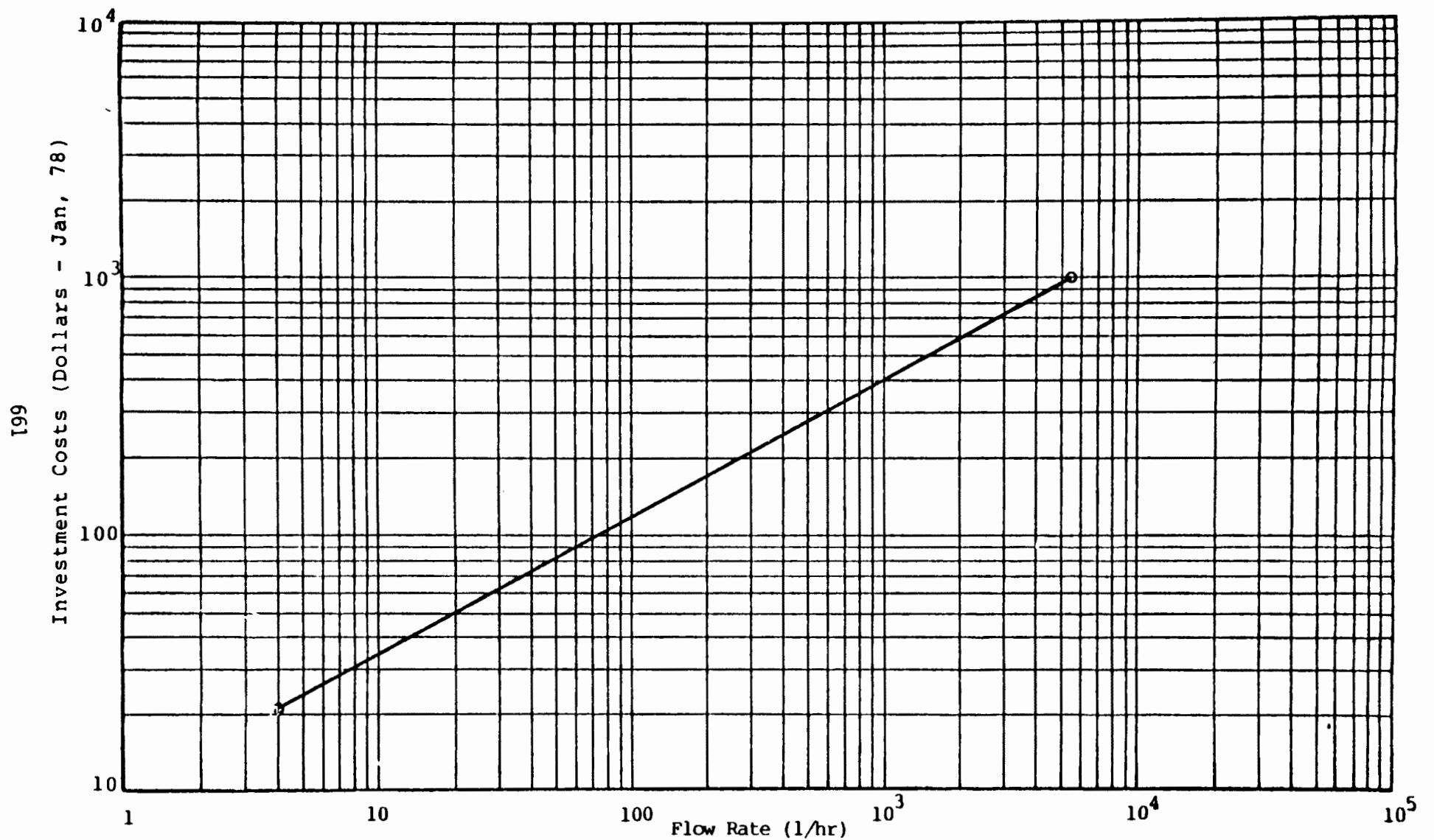
o Denotes flow limit ($\neq 0$) observed for this treatment in the non-lead subcategories of the battery industry.

Individual plants may differ because of variation in operating costs.

692
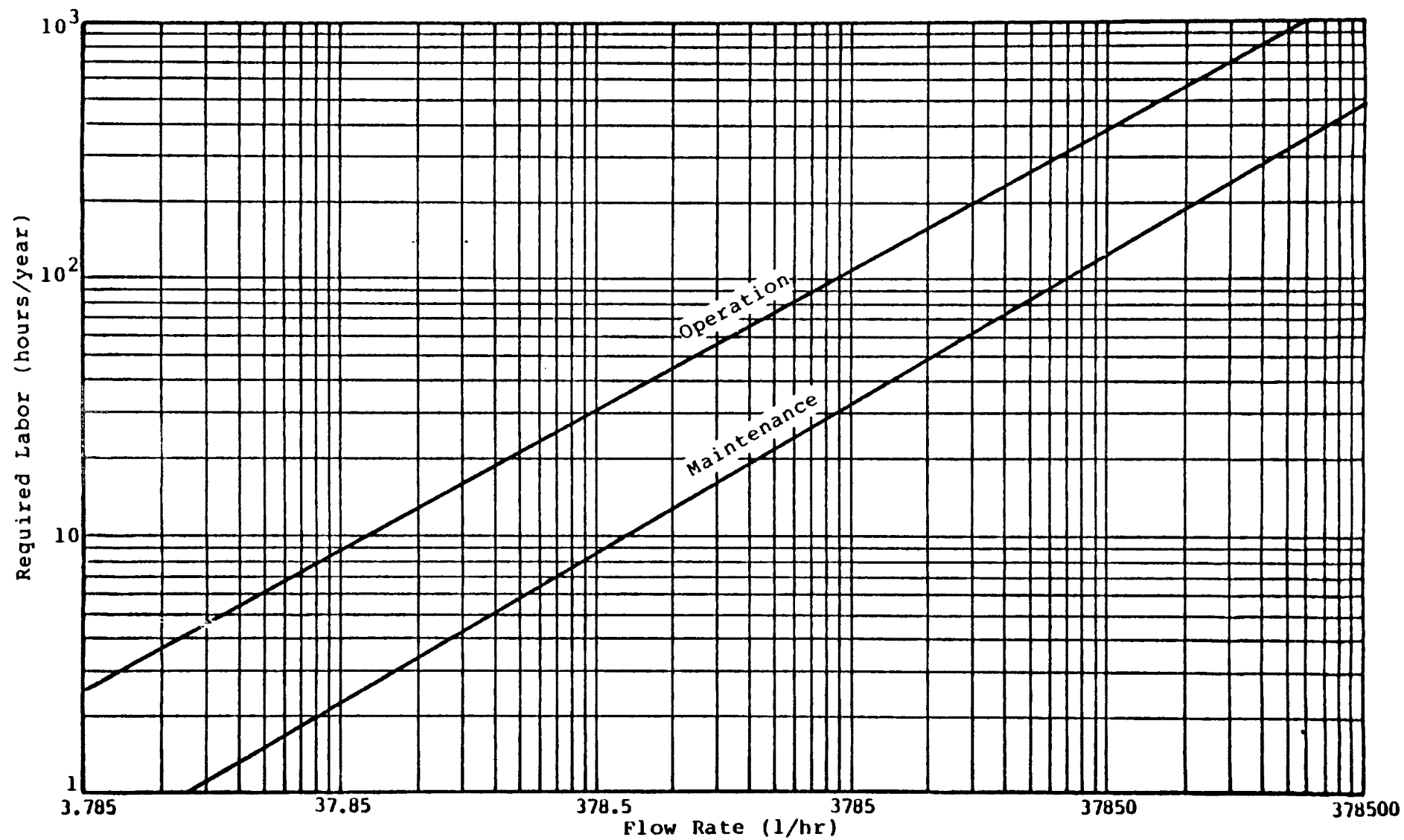
FIGURE VIII-20

NEUTRALIZATION LABOR REQUIREMENTS
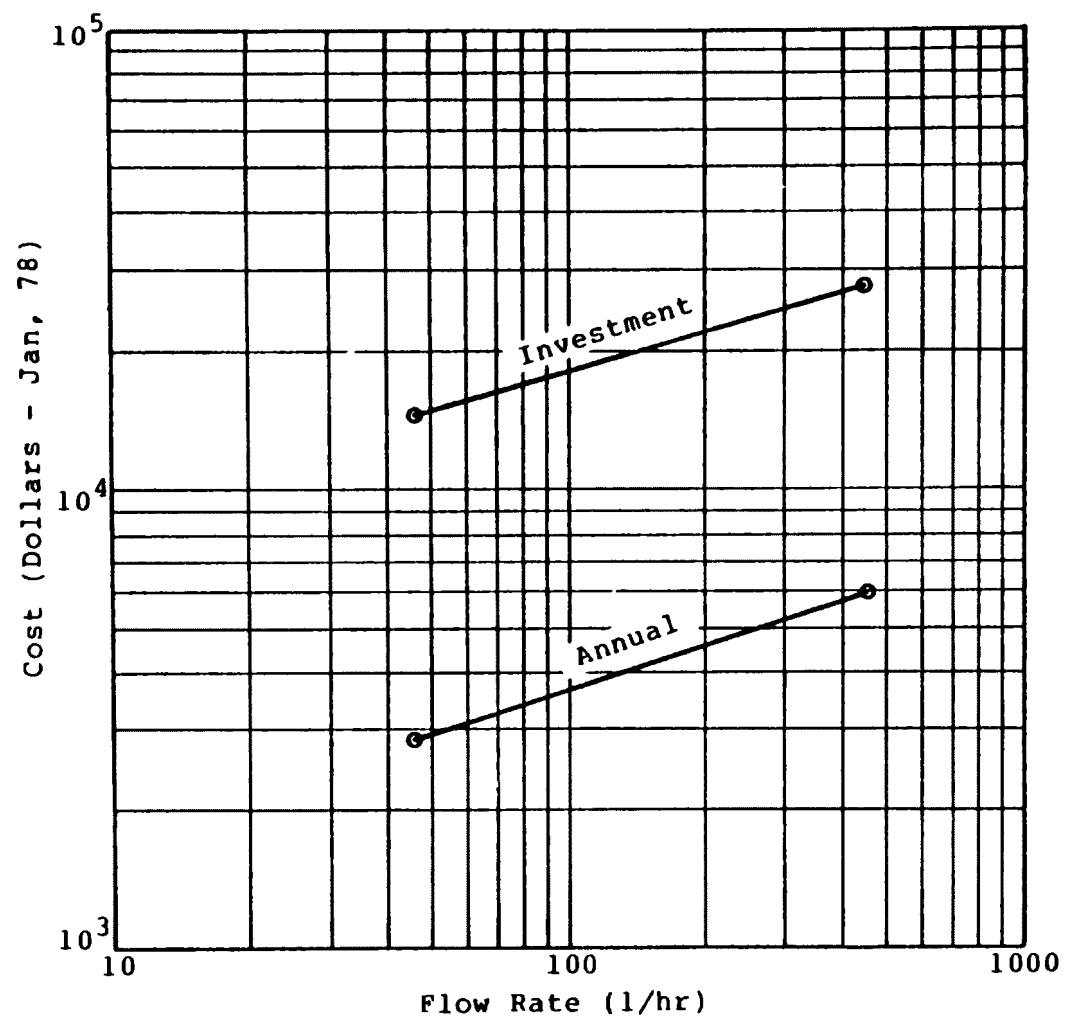
FIGURE VIII-21

CARBON ADSORPTION COSTS
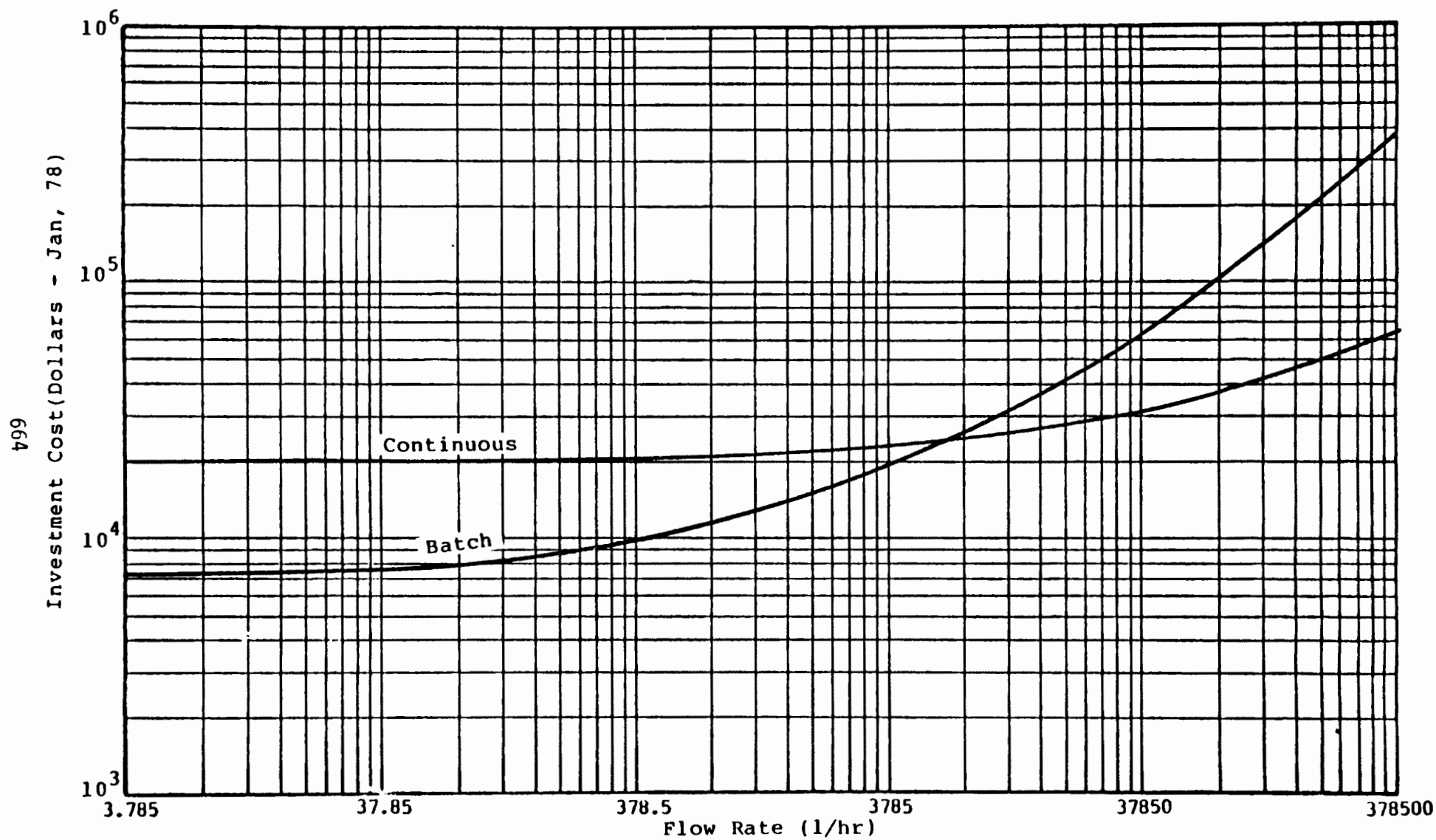
FIGURE VIII-22

CHEMICAL REDUCTION OF CHROMIUM
INVESTMENT COSTS

Batch (operation)

Continuous (operation)

Continuous (maintenance)

Minimum Continuous Process Maintenance

Annual Labor (hours/year)

695

Flow Rate (l/hr)

Batch maintenance equals 0 hours
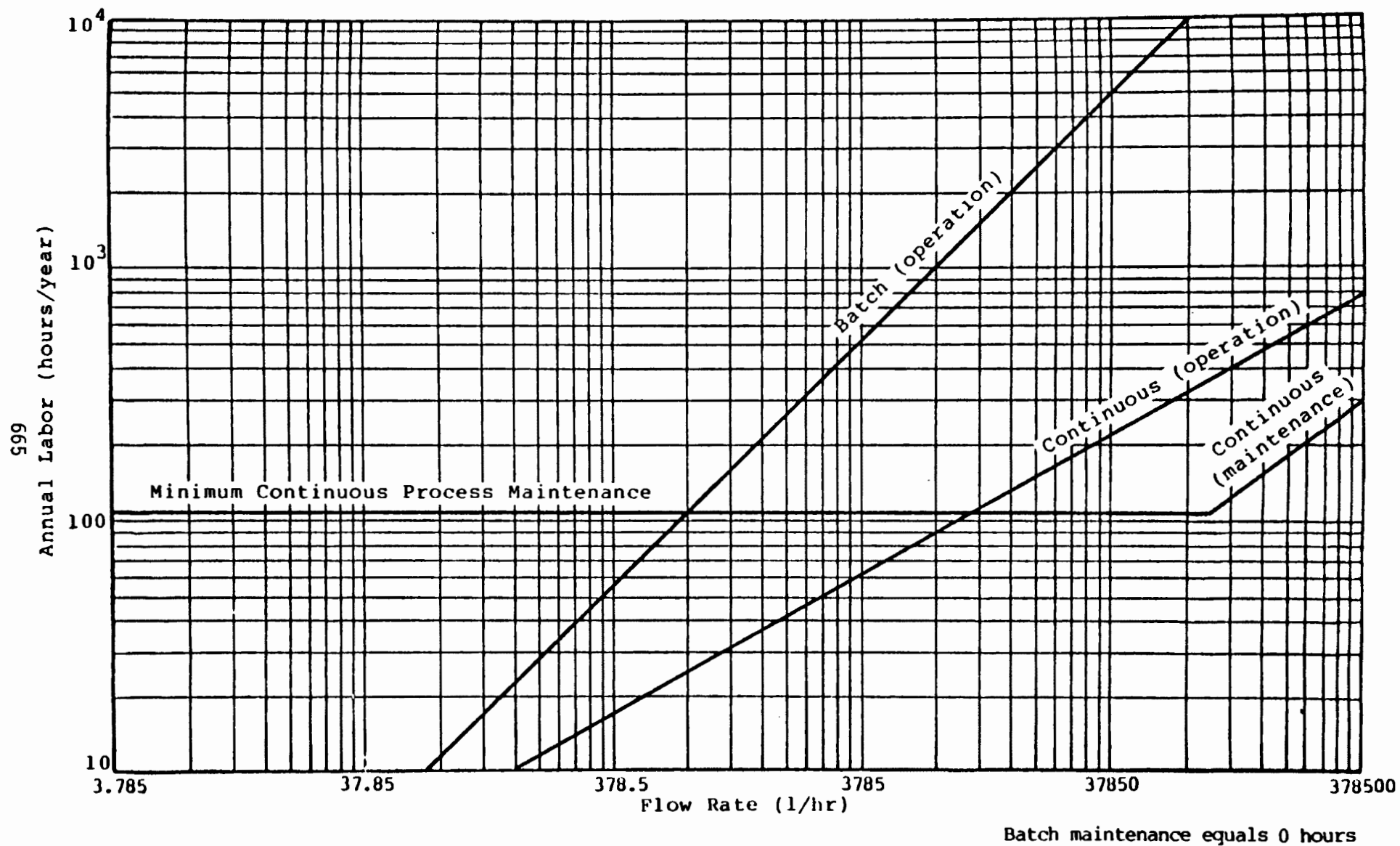
FIGURE VIII-23

ANNUAL LABOR FOR CHEMICAL REDUCTION OF CHROMIUM
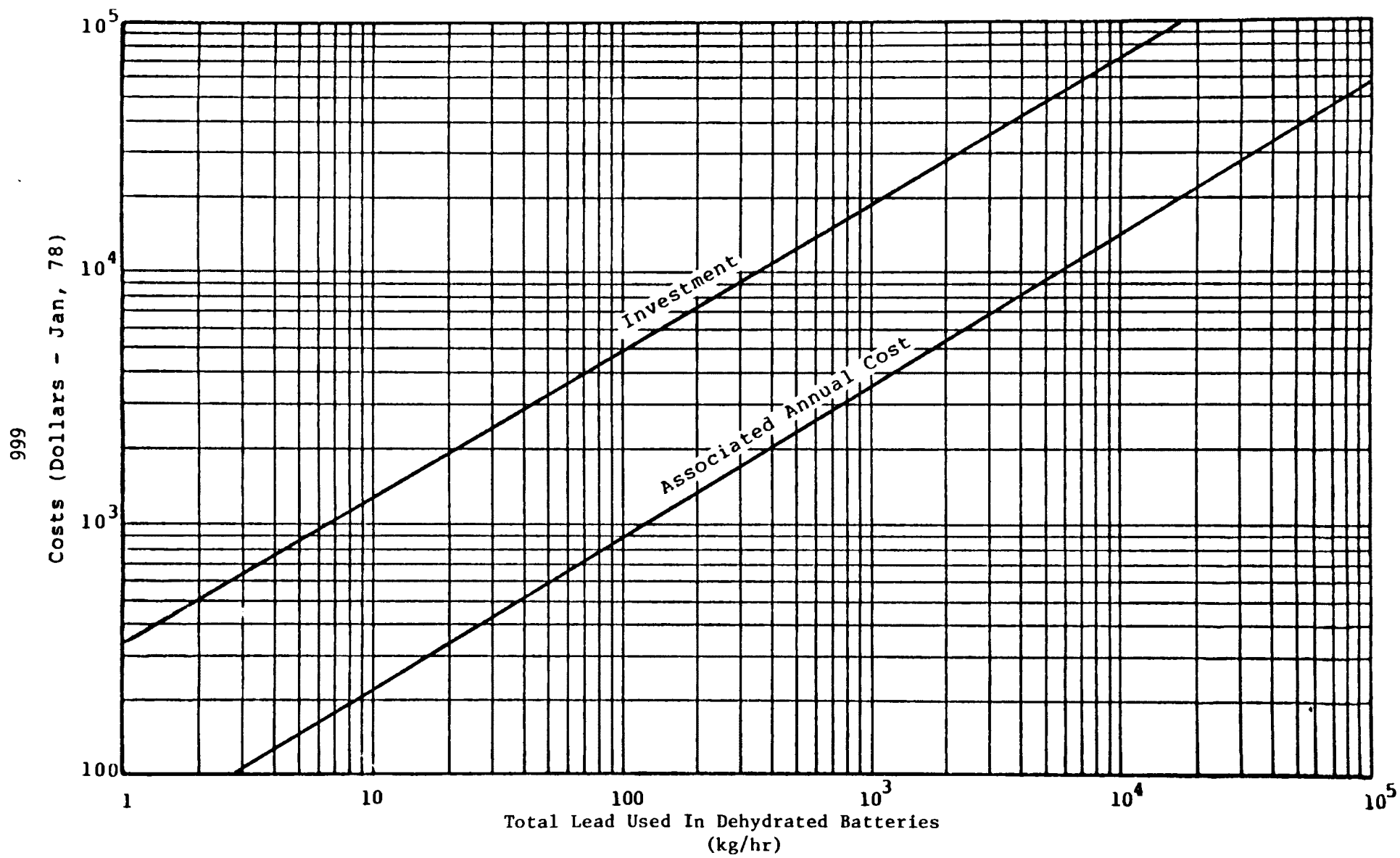
FIGURE VIII-24

LEAD SUBCATEGORY –   DEHYDRATED BATTERY IN – PROCESS CONTROL COSTS
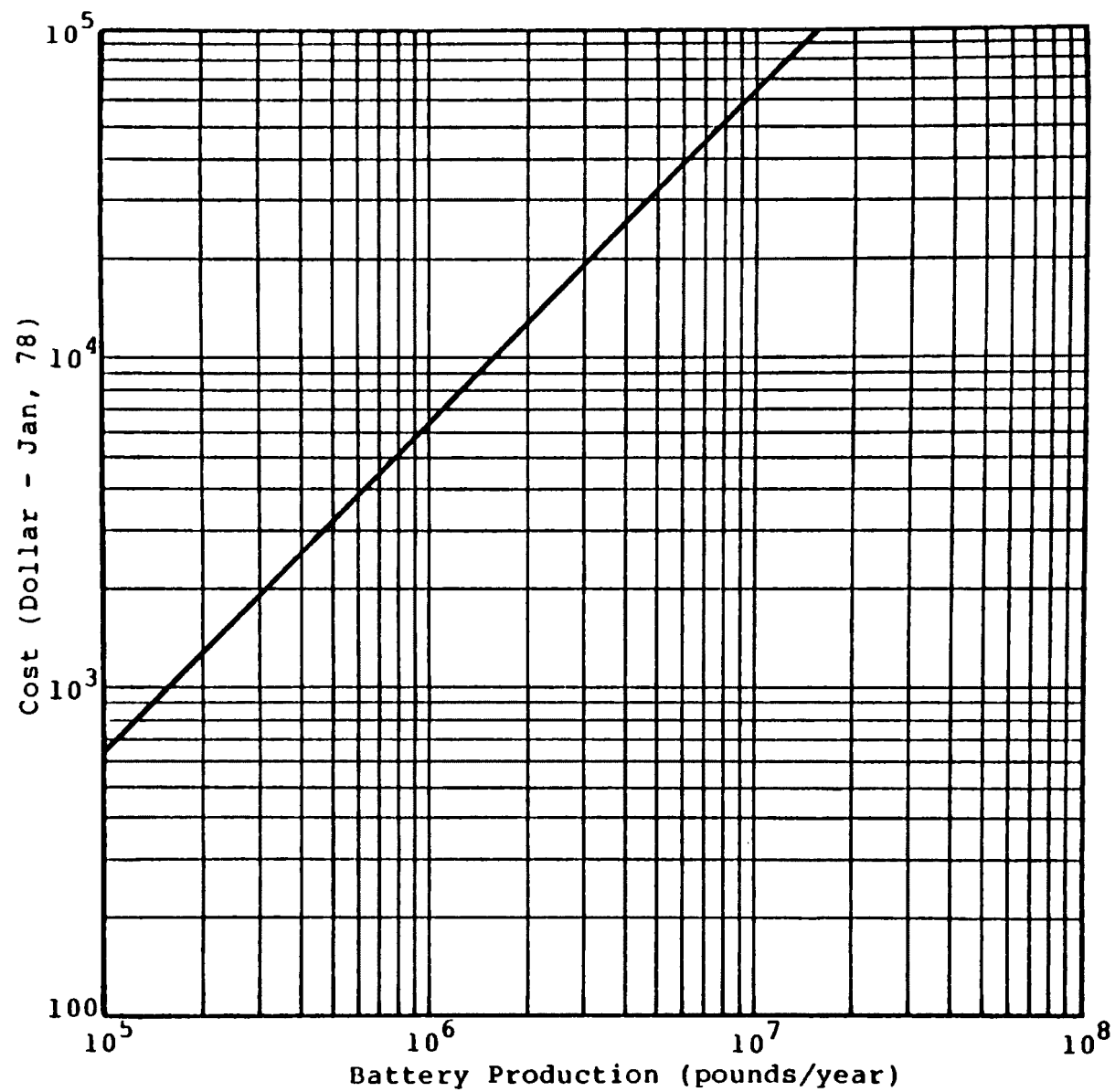
FIGURE VIII-25

LABOR FOR COUNTERCURRENT RINSES DEHYDRATED BATTERIES
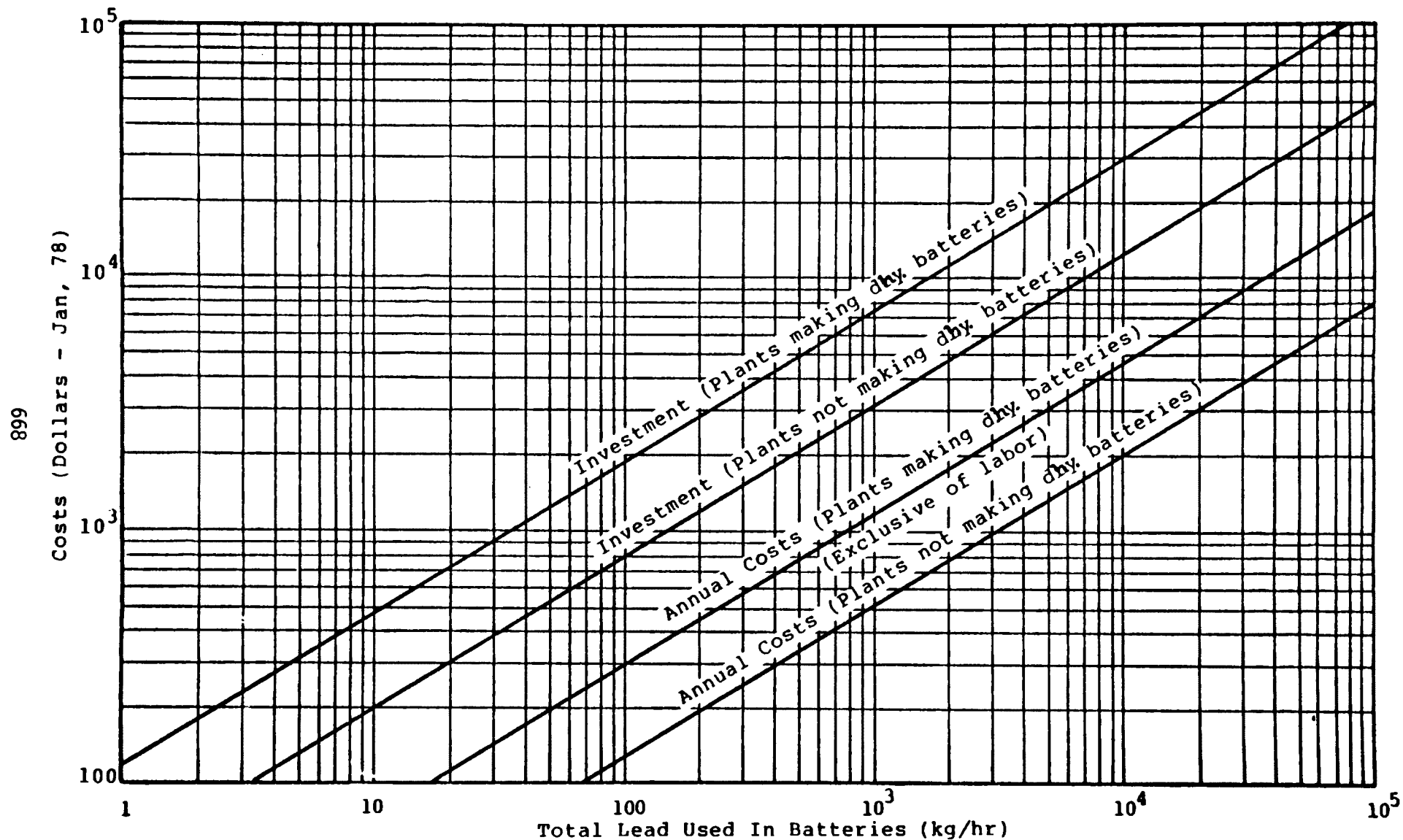
FIGURE VIII-26

IN-PROCESS PIPING AND SEGREGATION COSTS FOR THE LEAD SUBCATEGORY
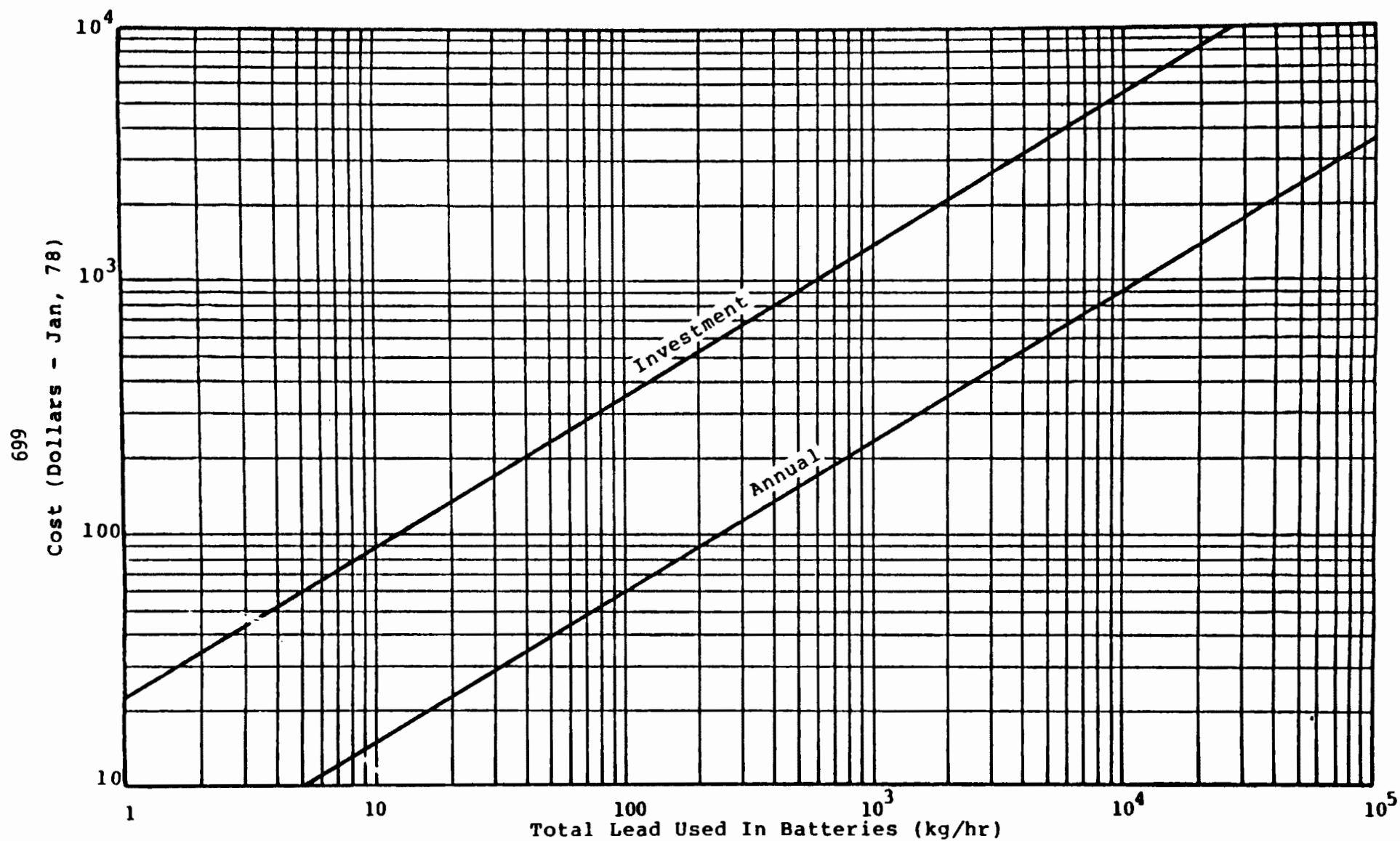
FIGURE VIII-27

HOLDING TANK COSTS
FOR BATTERY WASH WATER RECYCLE - LEAD SUBCATEGORY
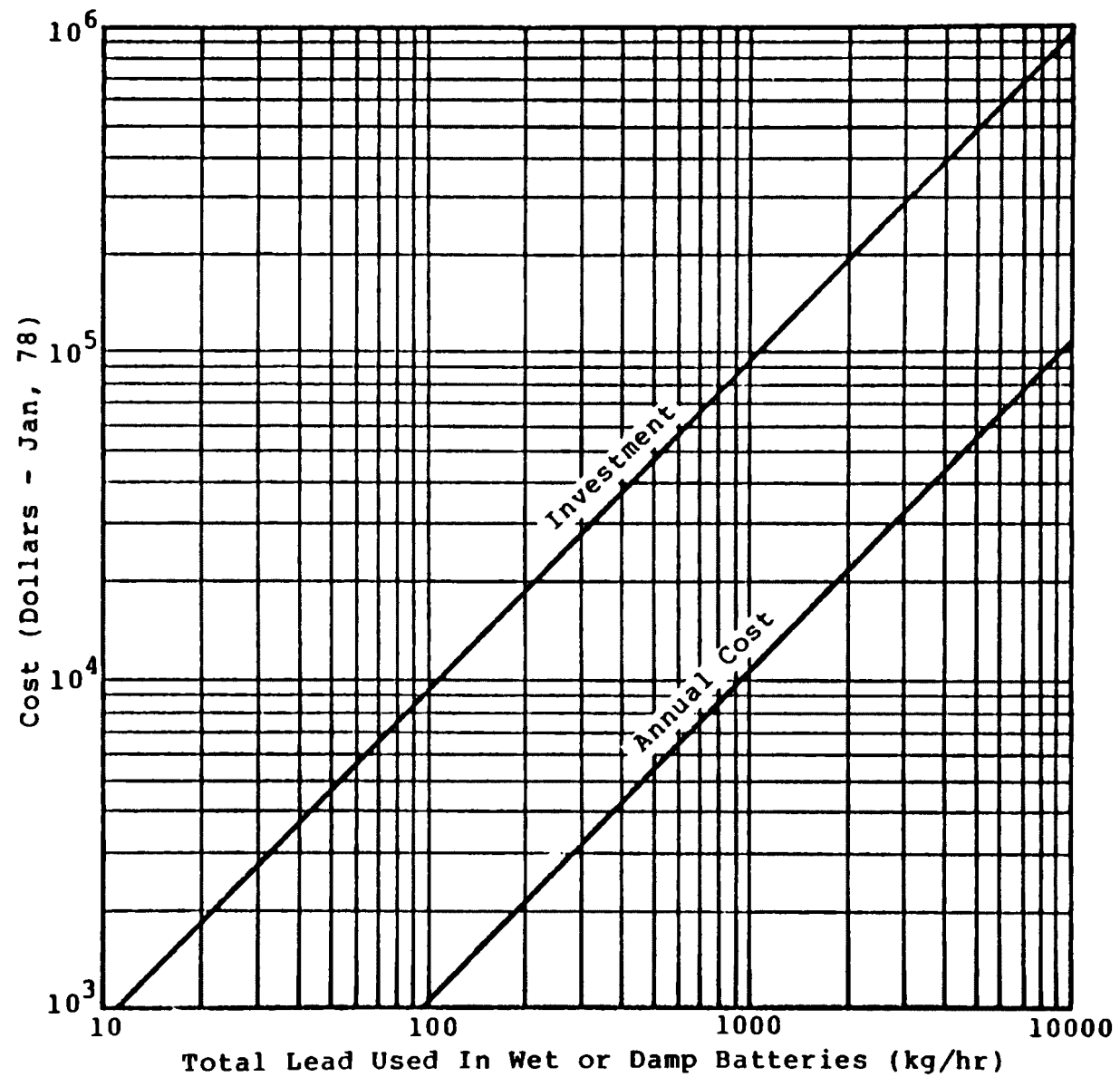
FIGURE VIII-28

IN-PROCESS COSTING FOR SLOW CHARGING BATTERIES LEAD SUBCATEGORY
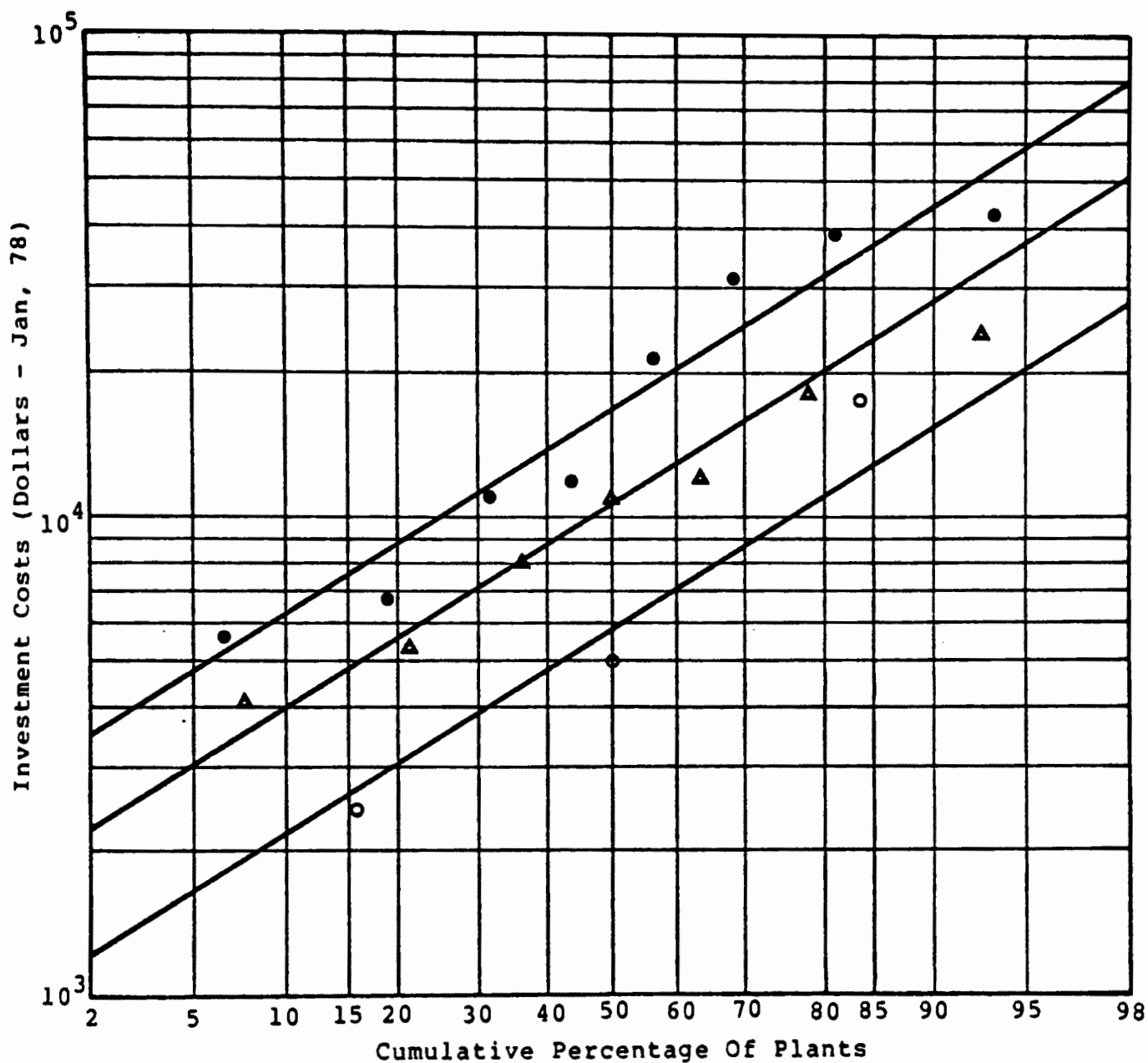
	Median	Average	N
BPT	$ 5910	$ 8250	3
BAT 1	$10700	$13400	8
BAT 2 and BAT 3	$16800	$21300	8

FIGURE VIII-29

IN-PROCESS INVESTMENT COSTS CADMIUM SUBCATEGORY

671
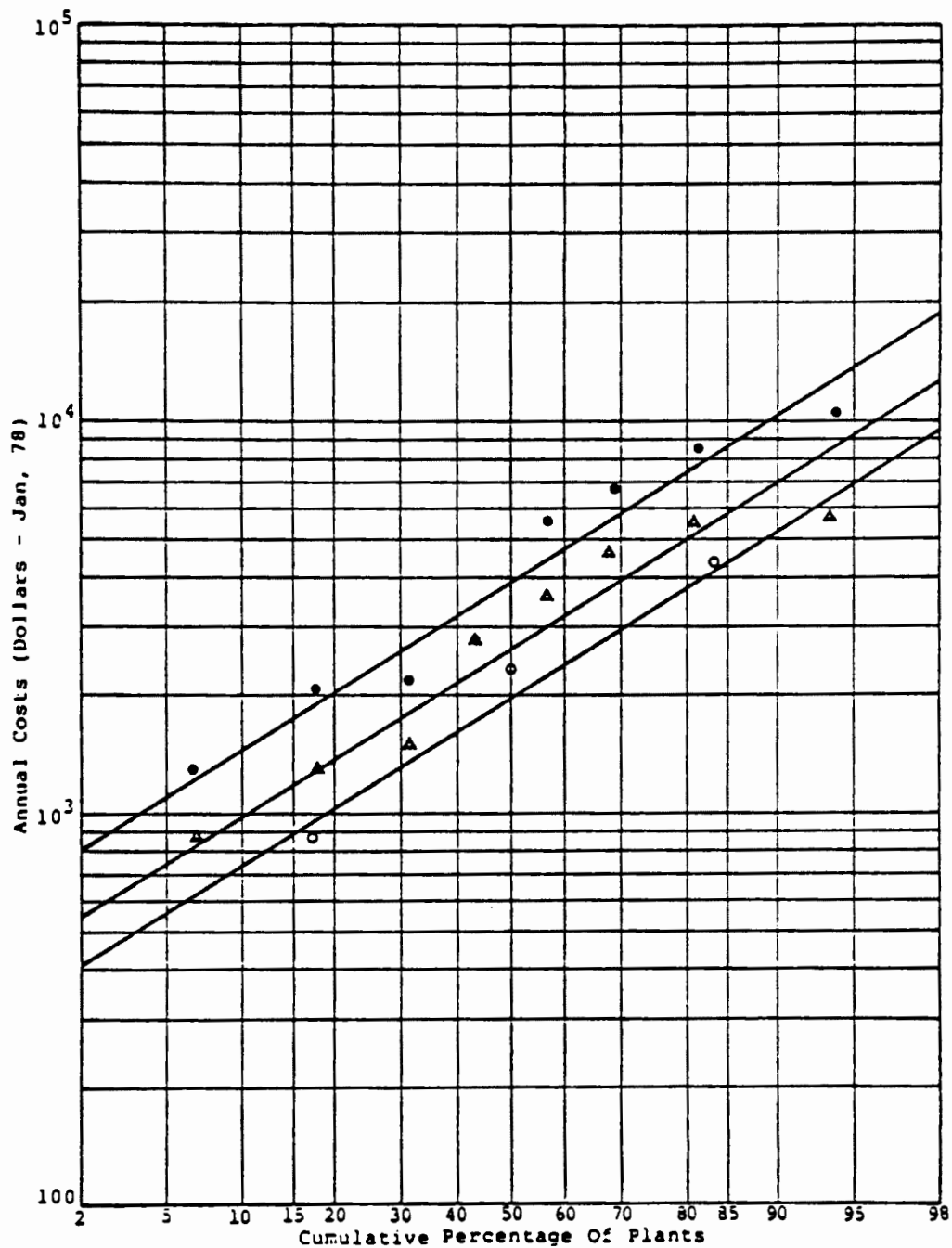
FIGURE VIII-30

IN-PROCESS ANNUAL COSTS CADMIUM SUBCATEGORY

672
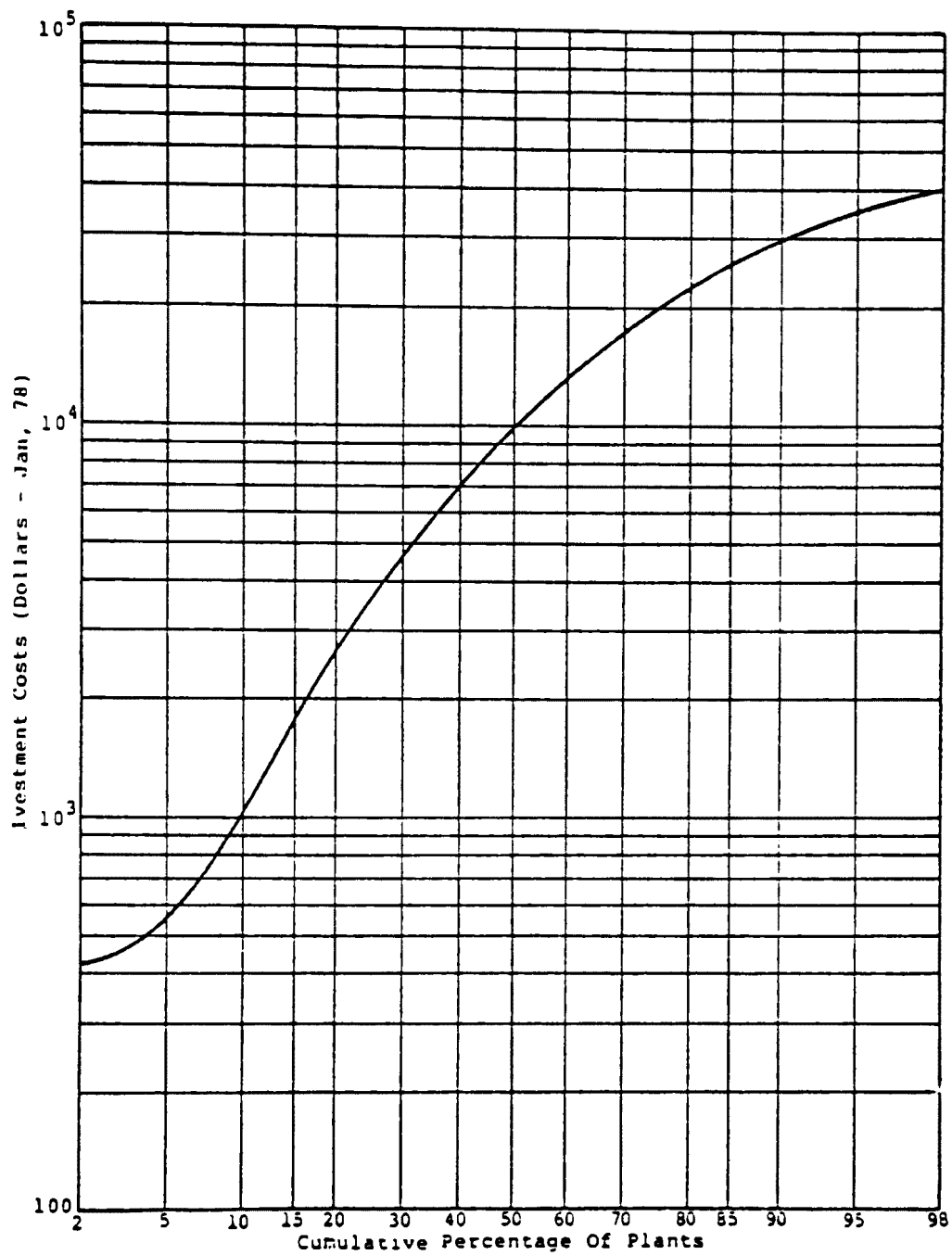
Median	$ 99,000	
Average	$129,600	
N	124	

FIGURE VIII-31

IN-PROCESS COSTS LEAD SUBCATEGORY

673
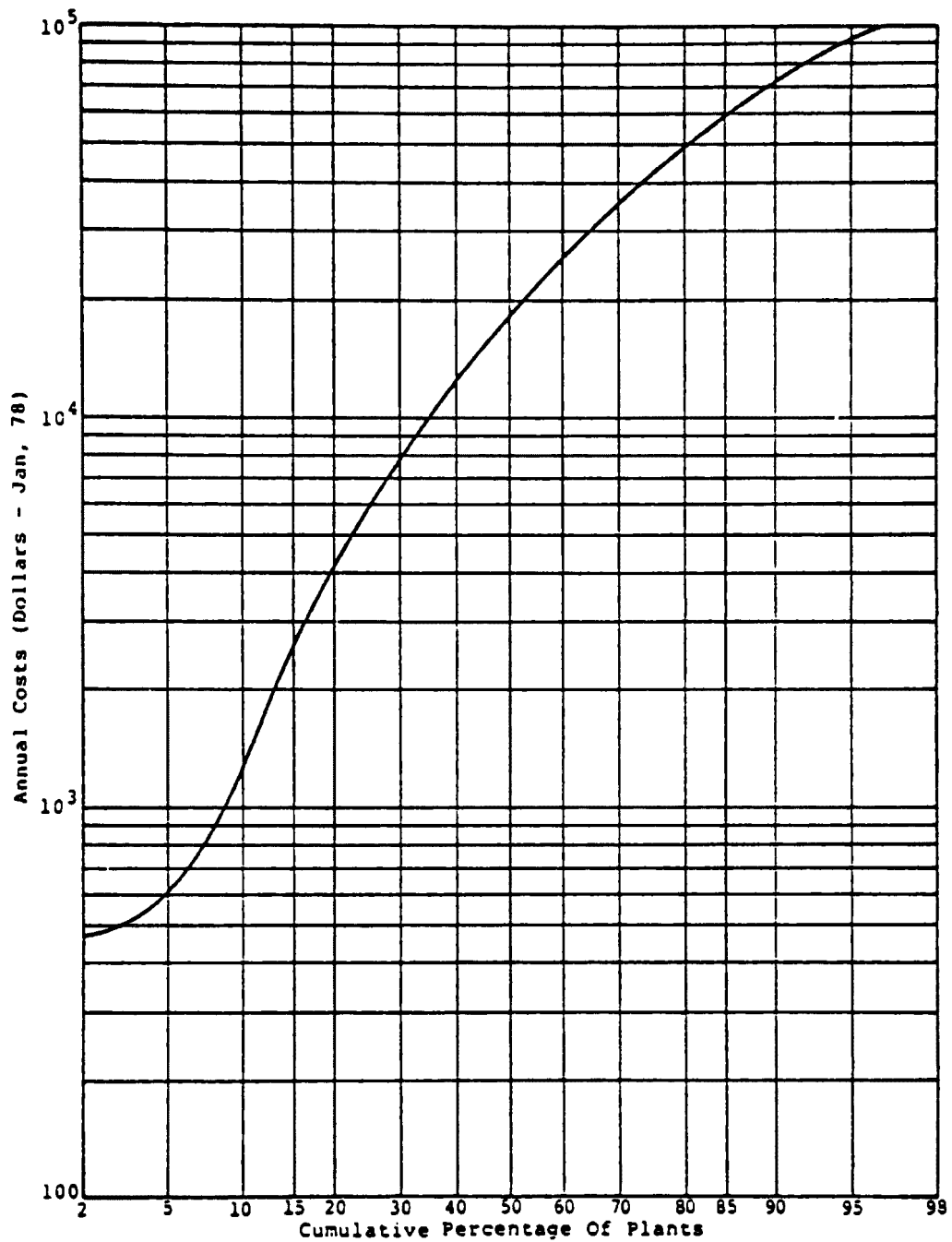
FIGURE VIII-32

IN-PROCESS COSTS LEAD SUBCATEGORY

674
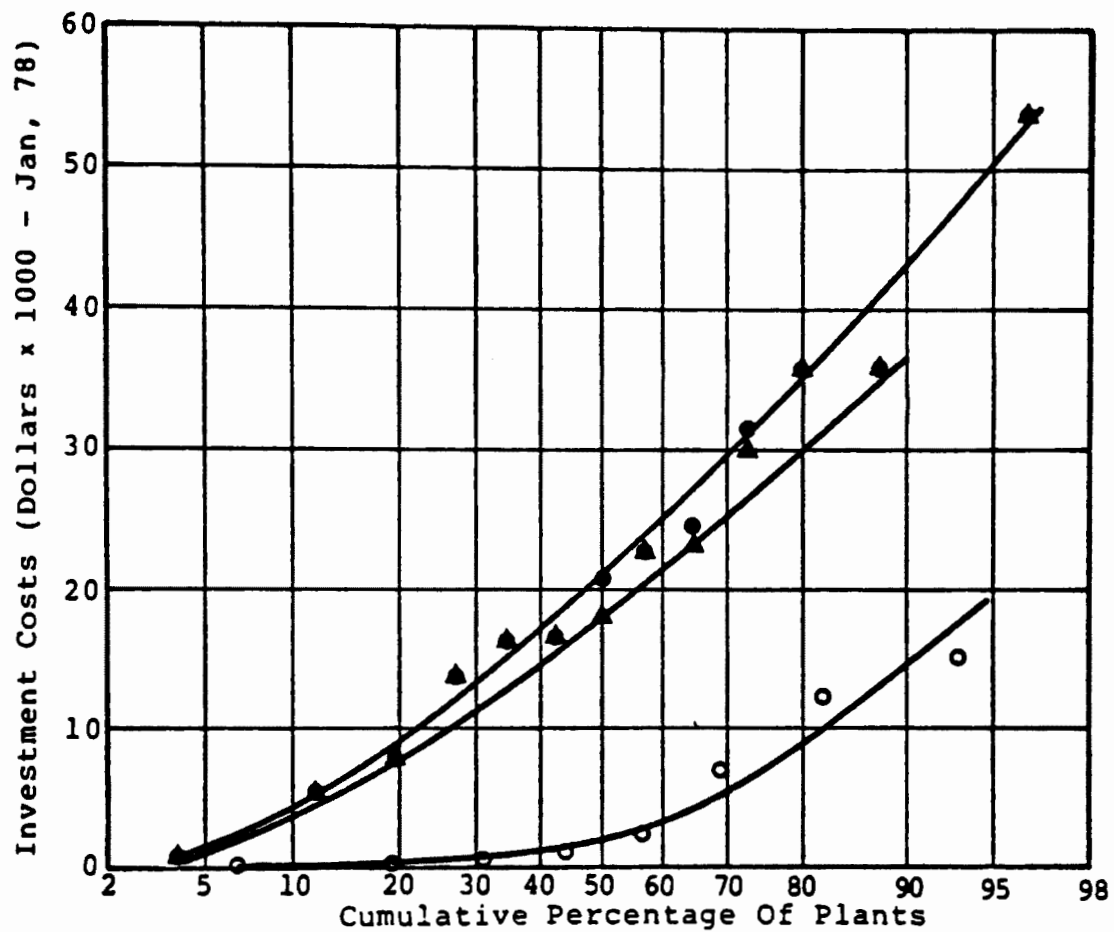
	Median	Average	N
BPT	$ 1900	$ 4870	8
BAT 1	$18000	$21500	13
BAT 2 and BAT 3	$21000	$22100	13

FIGURE VIII-33

IN-PROCESS INVESTMENT COSTS ZINC SUBCATEGORY

675
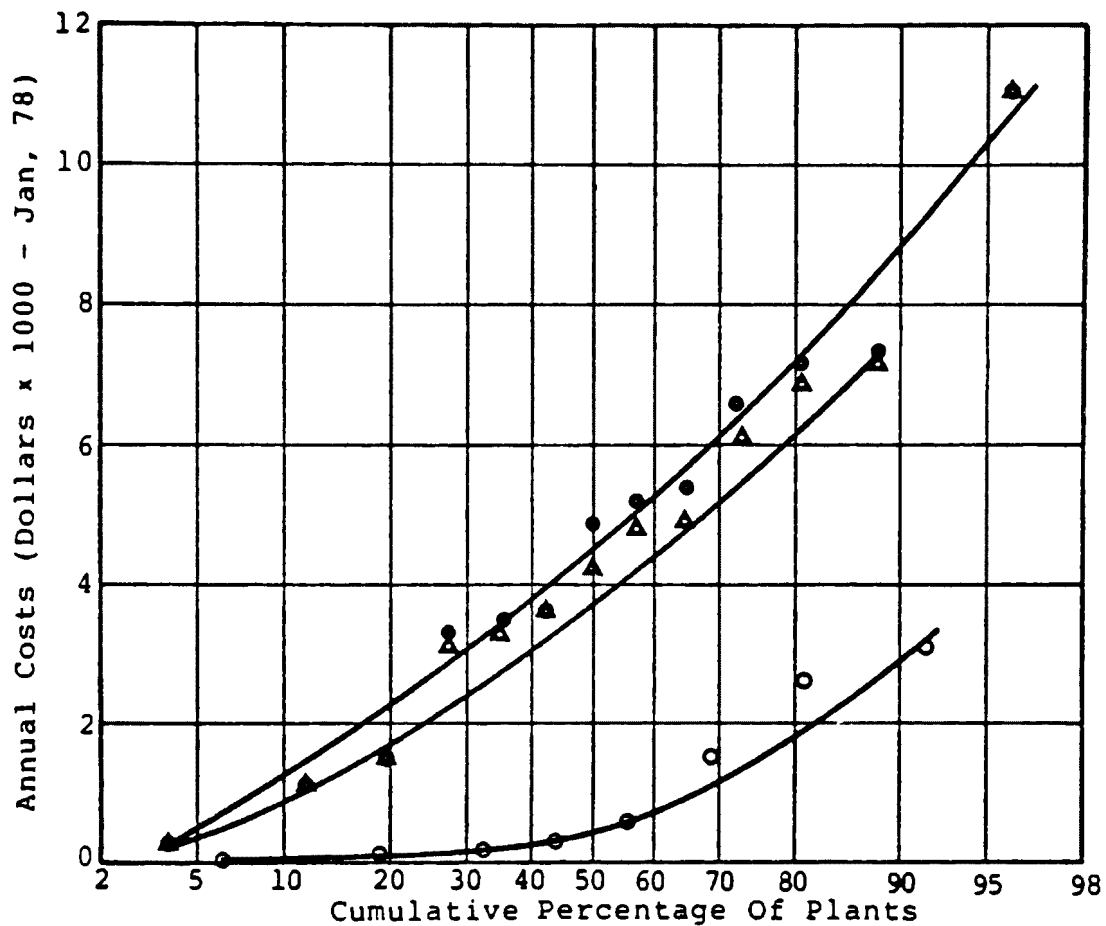
	Median	Average	N
BPT	$ 400	$ 1600	8
BAT 1	$3700	$ 4500	13
BAT 2 AND BAT 3	$4500	$ 4700	13

FIGURE VIII-34

IN-PROCESS ANNUAL COSTS ZINC SUBCATEGORY

TABLE VIII-1

COST PROGRAM POLLUTANT PARAMETERS

Parameter, Units	Parameter, Units
Flow, MGD	Oil, Grease, mg/l
pH, pH units	Hardness, mg/l $CaCO_3$
Turbidity, Jackson Units	Chemical Oxygen Demand, mg/l
Temperature, degree C	Algicides, mg/l
Dissolved Oxygen, mg/l	Total Phosphates, mg/l
Residual Chlorine, mg/l	Polychlorobiphenyls, mg/l
Acidity, mg/l $CaCO_3$	Potassium, mg/l
Alkalinity, mg/l $CaCO_3$	Silica, mg/l
Ammonia, mg/l	Sodium, mg/l
Biochemical Oxygen Demand mg/l	Sulfate, mg/l
Color, Chloroplatinate units	Sulfite, mg/l
Sulfide, mg/l	Titanium, mg/l
Cyanides, mg/l	Zinc, mg/l
Kjeldahl Nitrogen, mg/l	Arsenic, mg/l
Phenols, mg/l	Boron, mg/l
Conductance, micromhos/cm	Iron, Dissolved, mg/l
Total Solids, mg/l	Mercury, mg/l
Total Suspended Solids, mg/l	Nickel, mg/l
Settleable Solids, mg/l	Nitrate, mg/l
Aluminum, mg/l	Selenium, mg/l
Barium, mg/l	Silver, mg/l
Cadmium, mg/l	Strontium, mg/l
Calcium, mg/l	Surfactants, mg/l
Chromium, Total, mg/l	Beryllium, mg/l
Copper, mg/l	Plasticizers, mg/l
Fluoride, mg/l	Antimony, mg/l
Iron, Total, mg/l	Bromide, mg/l
Lead, mg/l	Cobalt, mg/l
Magnesium, mg/l	Thallium, mg/l
Molybdenum, mg/l	Tin, mg/l
Total Volatile Solids, mg/l	Chromium, Hexavalent, mg/l

677

TABLE VIII-2

TREATMENT TECHNOLOGY SUBROUTINES
Treatment Process Subroutines Presently Available

Spray/Fog Rinse
Countercurrent Rinse
Vacuum Filtration
Gravity Thickening
Sludge Drying Beds
Holding Tanks
Centrifugation
Equalization
Contractor Removal
Reverse Osmosis
Chemical Reduction of Chrom.
Chemical Oxidation of Cyanide
Neutralization
Clarification (Settling Tank/Tube Settler)
API Oil Skimming
Emulsion Breaking (Chem/Thermal)
Membrane Filtration
Filtration (Diatomaceous Earth)
Ion Exchange - w/Plant Regeneration
Ion Exchange - Service Regeneration
Flash Evaporation
Climbing Film Evaporation
Atmospheric Evaporation
Cyclic Ion Exchange
Post Aeration
Sludge Pumping
Copper Cementation

Sanitary Sewer Discharge Fee
Ultrafiltration
Submerged Tube Evaporation
Flotation/Separation
Wiped Film Evaporation
Trickling Filter
Activated Carbon Adsorption
Nickel Filter
Sulfide Precipitation
Sand Filter
Pressure Filter
Multimedia Granular Filter
Sump
Cooling Tower
Ozonation
Activated Sludge
Coalescing Oil Separator
Non Contact Cooling Basin
Raw Wastewater Pumping
Preliminary Treatment
Preliminary Sedimentation
Aerator - Final Settler
Chlorination
Flotation Thickening
Multiple Hearth Incineration
Aerobic Digestion
Lime Precipitation (metals)

Treatment Process Subroutines Currently Being Developed

Peroxide Oxidation
Air Stripping (Ammonia Removal)
Arsenic Removal
Fluoride Removal (Lime Addition)

TABLE VIII-3

WASTE WATER SAMPLING FREQUENCY

Waste Water Discharge (liters Per day)	Sampling Frequency
0 - 37,850	once per month
37,850 - 189,250	twice per month
189,250 - 378,500	once per week
378,500 - 946,250	twice per week
946,250+	thrice per week

TABLE VIII-4

INDEX TO TECHNOLOGY COST TABLES

TABLE	WASTE TREATMENT TECHNOLOGY
VIII-2.4	Hydroxide Precipitation And Settling
VIII-2.5	Sulfide Precipitation And Settling; Batch Treatment
VIII-2.6	Sulfide Precipitation And Settling; Continuous Treatment
VIII-2.7	Multimedia Filtration
VIII-2.8	Membrane Filtration
VIII-2.9	Reverse Osmosis
VIII-2.10	Vacuum Filtration
VIII-2.11	Holding And Settling Tanks
VIII-2.12	pH Adjustment
VIII-2.13	Aeration
VIII-2.14	Carbon Adsorption
VIII-2.15	Chrome Reduction

TABLE VIII-5

Lime Additions for Lime Precipitation

Stream Parameter	Lime Addition kg/kg (lbs/lb)
Acidity (as $CaCO_3$)	0.81
Aluminum	4.53
Antimony	1.75
Arsenic	2.84
Cadmium	2.73
Chromium	2.35
Cobalt	1.38
Copper	1.28
Iron (Dissolved)	2.19
Lead	0.205
Magnesium	3.50
Manganese	1.48
Mercury	0.42
Nickel	1.45
Selenium	3.23
Silver	0.39
Zinc	1.25

TABLE VIII-6

Reagent Additions for Sulfide Precipitation

Stream Parameter	Ferrous Sulfide Requirement kg/kg (lbs/lb)
Cadmium	0.86
Calcium	2.41
Chromium (Hexavalent)	1.86
Chromium (Trivalent)	2.28
Cobalt	1.64
Copper	1.52
Lead	0.47
Mercury	0.24
Nickel	1.65
Silver	0.45
Tin	0.81
Zinc	1.48

Sodium Bisulfide Requirement   =   0.65 x Ferrous Fulfide Requirement

Ferrous Sulfate Requirement   =   1.5 x Ferrous Sulfide Requirement

Lime Requirement   =   0.49 x $FeSO_4$(lbs) + 3.96 x NaHS(lbs) + 2.19 x lbs of Dissolved Iron

TABLE VIII-7

NEUTRALIZATION CHEMICALS REQUIRED

Chemical	Condition	A_0
Lime	pH less than 6.5	.00014
Sulfuric Acid	pH greater than 8.5	.00016

(Chemical demand, lbs/day) = Ao x Flow Rate (GPH) x Acidity
(Alkalinity, $mgCaCO_3/l$)

TABLE VIII-8

WATER TREATMENT COMPONENT COSTS

Process:	HYDROXIDE PRECIPITATION AND SETTLING		
Least cost:	BATCH	BATCH	CONTINUOUS
System flow rate: l/hr	4	23890	56780
gal/day	8	101000	360000
Investment:	18090	54630	72620
Annual costs:			
Capital costs	1134	3428	4557
Depreciation	1809	5463	7262
Operating & Maintenance costs (excluding energy)	2706	4491	8815
Energy costs	.001	17.72	61.29
Total annual costs:	$ 8650	$ 13400	$ 20700

TABLE VIII-9

WATER TREATMENT COMPONENT COSTS

Process:	SULFIDE PRECIPITATION AND SETTLING		
Least cost:	BATCH	BATCH	BATCH
System flow rate: 1/hr	4	95	6529
gal/day	8	600	13800
Investment:	3722	6101	31060
Annual costs:			
Capital costs	234	383	1949
Depreciation	372	610	3106
Operating & Maintenance costs (excluding energy)	824	2488	3351
Energy costs	.031	2.33	107
Total annual costs:	$ 1430	$ 3484	$ 8513

TABLE VIII-10

WATER TREATMENT COMPONENT COSTS

Process:	SULFIDE PRECIPITATION AND SETTLING		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: 1/hr	5677	10740	19240
gal/day	24000	45400	122000
Investment:	26820	32300	39030
Annual costs:			
Capital costs	1683	2027	2449
Depreciation	2682	3230	3903
Operating & Maintenance costs (excluding energy)	6615	9780	20331
Energy costs	4.88	8.84	23.36
Total annual costs:	$ 10980	$15050	$26710

TABLE VIII-11

WATER TREATMENT COMPONENT COSTS

Process:	MULTIMEDIA FILTRATION		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	4	5195	17348
gal/day	8	10980	110000
Investment:	261	21470	44800
Annual costs:			
Capital costs	16	1347	2811
Depreciation	26	2147	4430
Operating & Maintenance costs (excluding energy)	6065	6065	6065
Energy costs	284	284	284
Total annual costs:	$ 6391	$ 9843	$ 13640

TABLE VIII-12

WATER TREATMENT COMPONENT COSTS

Process:	MEMBRANE FILTRATION		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	26	380	1223
gal/day	112	2412	7755
Investment:	367	5280	16970
Annual costs:			
Capital costs	23	331	1065
Depreciation	37	527	1697
Operating & Maintenance costs (excluding energy)	3128	3300	3406
Energy costs	1650	2610	2694
Total annual costs:	$ 4838	$ 6769	$ 8862

TABLE VIII-13

WATER TREATMENT COMPONENT COSTS

Process:		REVERSE OSMOSIS		
Least cost:		CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate:	l/hr	4	182	16180
	gal/day	8	768	102600
Investment:		2707	15080	145100
Annual costs:				
Capital costs		170	946	9102
Depreciation		270	1508	14510
Operating & Maintenance costs (excluding energy)		419	799	40080
Energy costs		75	335	5895
Total annual costs:		$ 934	$ 3587	$ 69580

689

TABLE VIII-14

WATER TREATMENT COMPONENT COSTS

	Process:	VACUUM FILTRATION		
	Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate:	l/hr	25	168	326
	gal/day	106	210	1377
Investment:		25220	25220	25220
Annual costs:				
Capital costs		1582	1582	1582
Depreciation		2522	2522	2522
Operating & Maintenance costs (excluding energy)		3990	5179	5940
Energy costs		0	0	0
Total annual costs:		$ 8094	$ 9283	$ 10040

TABLE VIII-15

WATER TREATMENT COMPONENT COSTS

Process:	HOLDING AND SETTLING TANKS		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	4	151	3406
gal/day	8	640	7200
Investment:	700	1180	3592
Annual costs:			
Capital costs	44	74	225
Depreciation	70	118	359
Operating & Maintenance costs (excluding energy)	0	0	0
Energy costs	50	107	75
Total annual costs:	$ 164	$ 300	$ 660

TABLE VIII-16

WATER TREATMENT COMPONENT COSTS

Process:	pH ADJUSTMENT		
Least cost:	CONTINUOUS	CONTINUOUS	CONTINUOUS
System flow rate: l/hr	4	261	5267
gal/day	8	552	33400
Investment:	106	891	4144
Annual costs:			
Capital costs	7	56	260
Depreciation	11	89	414
Operating & Maintenance costs (excluding energy)	11	120	1190
Energy costs	.008	0.536	34
Total annual costs:	$ 29	$ 266	$ 1398

TABLE VIII-17

WATER TREATMENT COMPONENT COSTS

Process: AERATION

	Least cost:	CONTINUOUS	CONTINUOUS	
System flow rate:	l/hr	53	466	
	gal/day	223	984	
Investment:		800	1191	
Annual costs:				
Capital costs		50	75	
Depreciation		80	119	
Operating & Maintenance costs (excluding energy)		0	0	
Energy costs		101	52	
Total annual costs:		$ 231	$ 245	$

TABLE VIII-18

WATER TREATMENT COMPONENT COSTS

	Process:	CARBON ADSORPTION		
	Least cost:			
System flow rate:	1/hr	45	466	
	gal/day	192	984	
Investment:		14630	26180	
Annual costs:				
Capital costs		918	1643	
Depreciation		1463	2613	
Operating & Maintenance costs (excluding energy)		491	1767	
Energy costs		0.88	4.49	
Total annual costs:		$ 2873	$ 6033	$

TABLE VIII-19

WATER TREATMENT COMPONENT COSTS

Process:	CHROME REDUCTION		
Least cost:	BATCH	BATCH	BATCH
System flow rate: l/hr	26	61	3406
gal/day	56	128	7200
Investment:	7853	8355	19970
Annual costs:			
Capital costs	423	524	1253
Depreciation	785	835	1997
Operating & Maintenance costs (excluding energy)	7	16	891
Energy costs	108	103	103
Total annual costs:	$ 1393	$ 1479	$ 4244

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TABLE VIII-20

WATER EFFLUENT TREATMENT COSTS

CADMIUM SUBCATEGORY

Treatment level:	BPT		
Least cost:	Batch	Batch	Batch
System flow rate: l/hr	203.7	1576.8	12167
gal/day	860.8	9996	51424
Investment:	14070	27880	101800
Annual costs:			
Capital costs	883	1749	6390
Depreciation	1407	2788	10180
Operating & Maintenance costs (excluding energy)	3074	7739	9545
Energy costs	2.5	40	200
Total annual costs:	$ 5367	$ 12320	$ 26320
Cents per pound	21.5	12.3	5.26

TABLE VIII-21

WATER EFFLUENT TREATMENT COSTS

CALCIUM SUBCATEGORY

Treatment level: __BPT__

	Least cost:	BATCH	BATCH	
System flow rate:	l/hr	26.5	60.7	
	gal/day	56	128	
Investment:		23434	25520	
Annual costs:				
Capital costs		1470	1601	
Depreciation		2343	2551	
Operating & Maintenance costs (excluding energy)		1963	1951	
Energy costs		161	155	
Total annual costs:		$ 5938	$ 6258	$
Cents per pound		36.38	20.86	

TABLE VIII-22

WATER EFFLUENT TREATMENT COSTS

LEAD SUBCATEGORY

Treatment level: BPT

Least cost:	Batch	Batch	Batch
System flow rate: l/hr	3.8	3634	6624
gal/day	8	23040	42000
Investment:	24801	87235	313493
Annual costs:			
Capital costs	1556	5473	21367
Depreciation	2480	8723	20665
Operating & Maintenance costs (excluding energy)	1942	9835	9846
Energy costs	0	92	548
Total annual costs:	$ 5972	$ 24130	$ 52430
Cents per pound	1.07	0.215	0.635

TABLE VIII-23

WATER EFFLUENT TREATMENT COSTS

LECLANCHE SUBCATEGORY

Treatment level:		BPT		
Least cost:		BATCH	BATCH	BATCH
System flow rate:	l/hr	.484	143.8	306.6
	gal/day	1	608	1296
Investment:		120	1906	17283
Annual costs:				
Capital costs		8	119	1084
Depreciation		12	191	1728
Operating & Maintenance costs (excluding energy)		181	3502	10278
Energy costs		0	25	187
Total annual costs:		$ 201	$ 3837	$ 13277
Cents per pound		6.7	.011	.153

TABLE VIII-24

WATER EFFLUENT TREATMENT COSTS
LITHIUM SUBCATEGORY

Treatment level:	BPT		
Least cost:	BATCH	BATCH	BATCH
System flow rate: 1/hr	3.79	151	145.7
gal/day	8	320	308
Investment:	4015	5698	28601
Annual costs:			
Capital costs	252	358	1795
Depreciation	401	570	2860
Operating & Maintenance costs (excluding energy)	1096	1300	2051
Energy costs	100	216	156
Total annual costs:	$ 1850	$2443	$6801
Cents per pound	5.99	-	22.37

TABLE VIII-25

WATER EFFLUENT TREATMENT COSTS

MAGNESIUM SUBCATEGORY

Treatment level:	BPT		
Least cost:	BATCH	BATCH	BATCH
System flow rate: l/hr	54.5	666	5224
gal/day	230.4	1408	11040
Investment:	20908	28272	85196
Annual costs:			
Capital costs	1312	1774	5246
Depreciation	2091	2827	8520
Operating & Maintenance costs (excluding energy)	4529	2482	7663
Energy costs	202	108	275
Total annual costs:	$ 8134	$ 7191	$ 21803
Cents per pound	12.33	11.22	109.02

TABLE VIII-26

WATER EFFLUENT TREATMENT COSTS

ZINC SUBCATEGORY

Treatment level:	BPT		
Least cost:	BATCH	BATCH	CONTINUOUS
System flow rate: l/hr	120.9	1348.1	4838.7
gal/day	766	8547	20450
Investment:	18992	33926	74024
Annual costs:			
Capital costs	1192	2129	4644
Depreciation	1899	3393	7403
Operating & Maintenance costs (excluding energy)	9810	10760	13305
Energy costs	323	306	446
Total annual costs:	$ 13220	$ 16584	$25800
Cents per pound	0.346	0.108	5.16

TABLE VIII-27

WATER EFFLUENT TREATMENT COSTS

CADMIUM SUBCATEGORY

	Treatment level:	BAT-1		
	Least cost:	BATCH	BATCH	BATCH
System flow rate:	l/hr	111.2	836.8	6541.7
	gal/day	470.4	5305	13820
Investment:		19852	77600	110200
Annual costs:				
Capital costs		1245	4869	6915
Depreciation		1985	7760	11020
Operating & Maintenance costs (excluding energy)		3984	9988	12510
Energy costs		1.3	21.7	773
Total annual costs:		$ 7216	$ 22639	$ 31220
Cents per pound		28.9	22.6	6.24

TABLE VIII-28

WATER EFFLUENT TREATMENT COSTS

CADMIUM SUBCATEGORY

Treatment level:	BAT-2		
Least cost:	BATCH	BATCH	BATCH
System flow rate: 1/hr	96.3	481.9	5385.7
gal/day	416	3055	11384
Investment:	22690	50070	121850
Annual costs:			
Capital costs	1423	3142	7646
Depreciation	2269	5007	12185
Operating & Maintenance costs (excluding energy)	3642	9988	12230
Energy costs	25.1	347	897
Total annual costs:	$7358	$18483	$32950
Cents per pound	29.4	18.5	6.591

Title: TABLE VIII-29, WATER EFFLUENT TREATMENT COSTS, CADMIUM SUBCATEGORY

Treatment level: BAT-3
Least cost: BATCH, BATCH, BATCH

System flow rate: l/hr: 53.2, 419.8, 4272
gal/day: 224, 2664, 9024

Investment: 38320, 95580, 165500

Annual costs:
Capital costs: 2405, 5997, 10390
Depreciation: 3831, 9558, 16550
Operating & Maintenance costs (excluding energy): 10873, 13120, 15770
Energy costs: 863, 1407, 1648

Total annual costs: $17970, $30060, $44358
Cents per pound: 71.9, 30.1, 8.87

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TABLE VIII-29

WATER EFFLUENT TREATMENT COSTS

CADMIUM SUBCATEGORY

Treatment level:		BAT-3		
Least cost:		BATCH	BATCH	BATCH
System flow rate:	l/hr	53.2	419.8	4272
	gal/day	224	2664	9024
Investment:		38320	95580	165500
Annual costs:				
Capital costs		2405	5997	10390
Depreciation		3831	9558	16550
Operating & Maintenance costs (excluding energy)		10873	13120	15770
Energy costs		863	1407	1648
Total annual costs:		$17970	$30060	$44358
Cents per pound		71.9	30.1	8.87

TABLE VIII-30

WATER EFFLUENT TREATMENT COSTS

CALCIUM SUBCATEGORY

Treatment level:	BAT-1		
Least cost:	BATCH	BATCH	
System flow rate: 1/hr	26.5	60.7	
gal/day	56	128	
Investment:	24721	27627	
Annual costs:			
Capital costs	1551	1733	
Depreciation	2472	2763	
Operating & Maintenance costs (excluding energy)	8028	8016	
Energy costs	445	439	
Total annual costs:	$ 12500	$ 12950	$
Cents per pound	77.62	43.17	

TABLE VIII-31

WATER EFFLUENT TREATMENT COSTS

CALCIUM SUBCATEGORY

Treatment level:	BAT-2			
Least cost:	BATCH	BATCH		
System flow rate: l/hr	26.5	60.7		
gal/day	56	128		
Investment:	4412	4781		
Annual costs:				
Capital costs	277	300		
Depreciation	441	47S		
Operating & Maintenance costs (excluding energy)	1048	1109		
Energy costs	106	102		
Total annual costs:	S 1922	S 1990	S	
Cents per pound	11.94	6.63		

TABLE VIII-32

WATER EFFLUENT TREATMENT COSTS

LEAD SUBCATEGORY

Treatment level:	BAT-1		
Least cost:	Continuous	Batch	Batch
System flow rate: l/hr	2097	8733	3558
gal/day	4432	55370	19140
Investment:	11560	78280	491300
Annual costs:			
Capital costs	811	4342	32715
Depreciation	462	7828	21763
Operating & Maintenance costs (excluding energy)	1397	25842	6949
Energy costs	152	495	490
Total annual costs:	$ 2822	$ 38507	$61920
Cents per pound	0.513	0.111	0.0710

TABLE VIII-33

WATER EFFLUENT TREATMENT COSTS

LEAD SUBCATEGORY

	Treatment level:	BAT-2		
	Least cost:	Continuous	Batch	Batch
System flow rate:	l/hr	2097	8733	3558
	gal/day	4432	55370	19140
Investment:		11560	78280	491300
Annual costs:				
Capital costs		811	4342	32715
Depreciation		462	7828	21763
Operating & Maintenance costs (excluding energy)		1397	25842	6949
Energy costs		152	495	490
Total annual costs:		$2822	$ 38507	$ 61920
Cents per pound		0.513	0.111	0.0710

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TABLE VIII-34

WATER EFFLUENT TREATMENT COSTS

LEAD SUBCATEGORY

Treatment level:	BAT-3		
Least cost:	CONTINUOUS	CONTINUOUS	BATCH
System flow rate: l/hr	2082	26.5	3350
gal/day	4400	168	14160
Investment:	11560	80950	565900
Annual costs:			
Capital costs	811	4425	39490
Depreciation	462	7238	29490
Operating & Maintenance costs (excluding energy)	1397	8007	9464
Energy costs	152	2126	2108
Total annual costs:	$ 2822	$ 21800	$ 76000
Cents per pound	0.513	.771	.124

TABLE VIII-35

WATER EFFLUENT TREATMENT COSTS

LEAD SUBCATEGORY

Treatment level:	BAT-4		
Least cost:	CONTINUOUS	Continuous	BATCH
System flow rate: l/hr	2082	25.4	1692
gal/day	4400	107	7152
Investment:	11560	94019	650000
Annual costs:			
Capital costs	811	5825	44830
Depreciation	462	9116	33477
Operating & Maintenance costs (excluding energy)	10128	19430	26100
Energy costs	0	470	2715
Total annual costs:	$ 11401	$ 34852	$107100
Cents per pound	2.07	1.33	.175

TABLE VIII-36

WATER EFFLUENT TREATMENT COSTS

LITHIUM SUBCATEGORY

Treatment level:	BAT-1		
Least cost:	BATCH	BATCH	BATCH
System flow rate: l/hr	3.79	151	145.7
gal/day	8	320	308
Investment:	4015	5698	32157
Annual costs:			
Capital costs	252	358	2018
Depreciation	401	570	3216
Operating & Maintenance costs (excluding energy)	1096	1300	8116
Energy costs	100	216	440
Total annual costs:	$1850	$2443	$13790
Cents per pound	5.99	–	45.97

TABLE VIII-37

WATER EFFLUENT TREATMENT COSTS

LITHIUM SUBCATEGORY

Treatment level:	BAT-2			
Least cost:	BATCH	BATCH	BATCH	
System flow rate: l/hr	3.79	151	145.7	
gal/day	8	320	308	
Investment:	4015	5698	18652	

Annual costs:

Capital costs	252	358	1170
Depreciation	401	570	1865
Operating & Maintenance costs (excluding energy)	1096	1300	8068
Energy costs	100	216	387

Total annual costs:	$ 1850	$ 2443	S 11491
Cents per pound	5.99	-	38.30

TABLE VIII-38

WATER EFFLUENT TREATMENT COSTS

MAGNESIUM SUBCATEGORY

Treatment level:	BAT-1		
Least cost:	BATCH	BATCH	BATCH
System flow rate: l/hr	54.5	666	5224
gal/day	230.4	1408	11040
Investment:	22840	37371	115739
Annual costs:			
Capital costs	1436	2345	7262
Depreciation	2289	3737	11574
Operating & Maintenance costs (excluding energy)	10594	8553	14086
Energy costs	484	392	559
Total annual costs:	$ 14806	$ 15027	$ 33481
Cents per pound	22.27	23.44	167.41

TABLE VIII-39

WATER EFFLUENT TREATMENT COSTS

MAGNESIUM SUBCATEGORY

Treatment level:		BAT-2		
	Least cost:	BATCH	BATCH	BATCH
System flow rate:	l/hr	54.5	666	5224
	gal/day	230.4	1408	11040
Investment:		22890	37371	58591
Annual costs:				
Capital costs		1436	2345	3676
Depreciation		2289	3737	3859
Operating & Maintenance costs (excluding energy)		10594	8553	11076
Energy costs		486	392	378
Total annual costs:		$ 14806	$ 15027	$ 20990
Cents per pound		22.27	23.44	104.95

TABLE VIII-40

WATER EFFLUENT TREATMENT COSTS

MAGNESIUM SUBCATEGORY

Treatment level:	BAT-3		
Least cost:	BATCH	BATCH	BATCH
System flow rate: l/hr	54.5	666	5224
gal/day	230.4	1408	11040
Investment:	43457	61907	73784
Annual costs:			
Capital costs	2727	3884	4630
Depreciation	4346	6191	7378
Operating & Maintenance costs (excluding energy)	11078	11076	10284
Energy costs	386	453	345
Total annual costs:	$ 18537	$ 21604	$ 22637
Cents per pound	27.88	108.02	35.32

TABLE VIII-41

WATER EFFLUENT TREATMENT COSTS

ZINC SUBCATEGORY

Treatment level:	BAT-1		
Least cost:	BATCH	BATCH	BATCH
System flow rate: l/hr	227.1	30.7	447.4
gal/day	1200	130	1891
Investment:	15846	34638	72570
Annual costs:			
Capital costs	994	2173	4553
Depreciation	1585	3464	7257
Operating & Maintenance costs (excluding energy)	9122	9875	11253
Energy costs	288	388	539
Total annual costs:	$ 11989	$ 15900	$ 23602
Cents per pound	0.25	3.18	1.30

TABLE VIII-42

WATER EFFLUENT TREATMENT COSTS

ZINC SUBCATEGORY

Treatment level:		BAT-2		
	Least cost:	BATCH	BATCH	CONTINUOUS
System flow rate:	l/hr	224.8	382.9	447.4
	gal/day	949	3400	1891
Investment:		20593	42279	81843
Annual costs:				
Capital costs		1242	2652	5136
Depreciation		2060	4228	8184
Operating & Maintenance costs (excluding energy)		6358	8221	10070
Energy costs		1744	2690	1075
Total annual costs:		$ 11450	$ 17791	$ 25370
Cents per pound		0.239	.116	1.4

TABLE VIII-43

WATER EFFLUENT TREATMENT COSTS

ZINC SUBCATEGORY

Treatment level:		BAT-3		
Least cost:		BATCH	CONTINUOUS	CONTINUOUS
System flow rate:	l/hr	70.3	110.5	1227.5
	gal/day	446	700	7783
Investment:		20343	45930	112400
Annual costs:				
Capital costs		1275	2882	7054
Depreciation		2035	4593	11240
Operating & Maintenance costs (excluding energy)		1232	16740	20610
Energy costs		358	1067	1964
Total annual costs:		$ 4900	$ 25280	$ 40880
Cents per pound		.0463	.661	1.77

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TABLE VIII-44

NONWATER QUALITY ASPECTS OF WASTE WATER TREATMENT

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh 1000 liters	Fuel	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Chemical Reduction	1.0	---	Mixing	None	None	None	-----
Skimming	0.01-.3	---	Skimmer Drive	None	None	Concentrated	5-50 (oil)
Clarification	0.1-3.2	---	Sludge Collector Drive	None	None	Concentrated	1-10
Flotation	1.0	---	Recirculation Pump, Compressor, Skim	None	None	Concentrated	3-5
Chemical	0.3	---	Mixing	None	None	None	-----
Oxidation By Chlorine Oxidation By Ozone	0.5-5.0	---	Mixing Ozone Generation	None	None	None	-----
Chemical Precipitation	1.02	---	Flocculation Paddles, mixers	None	None	Concentrated	1-10
Sedimentation	0.1-3.2	---	Sludge Collector Drive	None, Possible H_2S Evolution	None	Concentrated	1-3
Deep Bed	0.10	---	Head, Backwash Pumps	None	None	Concentrated	Variable
Ion Exchange	0.5	---	Pumps	None	Not Objectionable	None	N/A
Adsorption	0.1	---	Pumps, Evaporate During Regeneration	None	None	None/Waste Carbon	40
Evaporation	---	*2.5	Evaporate Water	None	None	Concentrated/ Dewatered	50-100
Reverse Osmosis	3.0	---	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Ultrafiltration	1.25-3.0	---	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Membrane Filtration	1.25-3.0	---	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Electrochemical Chromium Reduction	0.2-0.8	---	Rectifier, Pump	None	None	Concentrated	1-3
Electrochemical Chromium Regeneration	2.0	--	Regeneration, Pump	None	None	None	-----

* 10^6 BTU/1000 liters

TABLE VIII-45

NONWATER QUALITY ASPECTS OF SLUDGE AND SOLIDS HANDLING

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh / ton dry solids	Fuel kwh / ton dry solids	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Sludge Thickening	29-930	----	Skimmer, Sludge Rake Drive	None	None	Concentrated	4-27
Pressure Filtration	21	----	High Pressure Pumps	None	None	Dewatered	25-50
Sand Bed Drying	----	35	Removal Equipment	None	None	Dewatered	15-40
Vacuum Filter	16.7-66.8	----	Vacuum Pump, Rotation	None	Not Objectionable	Dewatered	20-40
Centrifugation	0.2-98.5	----	Rotation	None	Not Objectionable	Dewatered	15-50
Landfill	----	20-980	Haul, Land-fill 1-10 Mile Trip	None	None	Dewatered	N/A
Lagooning	----	36	Removal Equipment	None	None	Dewatered	3-5

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SECTION IX
BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

[Introductory Note - This section presents the strategy and technical methodology for BPT. Further discussion and the development of regulatory values will be included at proposal]

This section describes the best practicable control technology currently available (BPT) for each subcategory within the battery manufacturing category. BPT reflects existing treatment and control practices at battery manufacturing plants of various sizes, ages, and manufacturing processes. Particular consideration is given to the treatment in-place at plants within each subcategory.

The factors considered in defining BPT include the total cost of application of technology in relation to the effluent reduction benefits from such application, the age of equipment and facilities involved, the processes employed, non-water quality environmental impacts (including energy requirements), and other factors considered appropriate by the Administrator. In general, the BPT technology level represents the best existing practices at plants of various ages, sizes, processes or other common characteristics. Where existing practice is uniformaly inadequate, BPT may be transferred from a different subcategory or category. Limitations based on transfer of technology must be supported by a conclusion that the technology is, indeed, transferrable and a reasonable prediction that it will be capable of achieving the prescribed effluent limits. (See Tanner's Council of America V. Train Supra). BPT focuses on end-of-pipe treatment rather than process changes or internal controls, except where such are common industry practices.

TECHNICAL APPROACH TO BPT

The category was studied and previous effluent guideline development work was examined to identify the processes used, wastewater generated, and treatment practices employed by battery manufacturing operations. After preliminary subcategorization and additional information collection using both dcp forms and specific plant sampling and analysis, the total information about the category was examined. On the basis of that examination, the subcategorization was revised as described in Section IV to reflect anode material and electrolyte. Discrete process elements shown in Table IV-1 (Page 90) were identified to serve as the basis for effluent limitations and standards. The collected information was then examined to determine what constituted an appropriate BPT. Some of the salient considerations are:

o   Each subcategory encompasses a number of different process operations (elements) which can generate wastewater. These may be combined in many different ways in battery manufacturing facilities.

o   Wastewater streams from different operations within each subcategory are often treated in combined systems, and are usually similar in treatment requirements.

o   The most significant pollutants in process wastewater from different subcategories are generally different. Combined treatment or discharge of wastewater from different subcategories occurs quite infrequently.

o   Most wastewater streams generated in this category are characterized by high levels of toxic metals (including cadmium, mercury, and lead).

o   Treatment practices vary among different subcategories. Observed practices include: chemical precipitation of metals as hydroxide, carbonate, and sulfides; amalgamation; sedimentation; filtration; ion exchange; and carbon adsorption.

Some of the factors outlined above which must be considered in establishing effluent limitations based on BPT have already been addressed by this document. The age of equipment and facilities involved and the processes employed were taken into account in subcategorization and are discussed fully in Section IV. Nonwater quality impacts and energy requirements are considered in Section VIII.

The battery manufacturing category comprises seven subcategories each of which includes a number of different process operations which generate wastewater. Based on the considerations presented above, a general approach to BPT was defined in which all process waste streams within a subcategory are subjected to treatment in a single (common) treatment system. Since the different waste streams do not differ significantly in treatability, the treatment technology performance or attainable effluent concentrations from treatment do not depend on the relative contribution of each wastewater source. This fact allows the development of uniform effluent limitations applicable to all of the manufacturing process variations encountered in each subcategory. This is accomplished by the strategy of providing mass discharge allowances for each process element within the subcategory based on the pollutant concentrations attainable from the combined subcategory treatment system and wastewater flow allowances for each individual process element.

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BPT for all subcategories must provide for removal of metals and suspended solids. This requires chemical precipitation and sedimentation (and, in some cases, polishing filtration). However, optimum conditions and treatment chemicals differ for wastewater streams from different subcategories. A reasonable degree of in process water flow control is also found in BPT for all subcategories. This is defined by the median flow observed in present practice for each process element. Consequently, it was determined that a different BPT is appropriate to each subcategory.

Finally, treatment was determined to be uniformaly inadequate in some subcategories. As a result, BPT is based on transfer of technologies in some cases, although the transfer may only involve proper maintenance and operation of technologies presently in place within the subcategory.

Specific factors must be considered and unique technical approaches must be defined for each subcategory. These are addressed together with the identified BPT for each subcategory in the ensuing sections.

Specific Regulation of Priority Pollutants

Final selection of priority pollutants will be based on raw wastewater concentration levels and technical judgement factors covered in Section X. Limitations will be based on treatment levels covered in Section - VII and median flows for each process element presented in Section V.

CADMIUM SUBCATEGORY

In defining BPT for the cadmium subcategory the information collected to characterize process wastewater and present treatment practices was carefully reviewed. The results of this review indicated that treatment technologies presently applied at many plants in the subcategory are suitable for consideration as BPT. However, many existing treatment facilities are observed to be inadequately designed, maintained, and operated. Few in-process control techniques are widely applied in this subcategory. Consequently, BPT consists primarily of end-of-pipe treatment.

Wastewater generated by plants in the cadmium subcategory contains significant quantities of cadmium, nickel, silver, and suspended solids. Cadmium is discharged from anode processing operations whereas nickel, nickel and cadmium, or silver may be used in cathode manufacture. As shown in Section V, essentially all streams contain toxic metals, and none are observed to contain pollutants requiring separate treatment except for silver powder production which will be regulated the same as silver powder production in the zinc subcategory.

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The pollutant concentrations discharged from these treatment systems are observed to vary widely and to frequently exceed those listed in Table VII-11 as attainable by application of chemical precipitation and sedimentation technology. On-site observations at plants in this subcategory indicate that this may be attributed to variable and generally poor control over treatment conditions, especially for suspended solids removal. Often "settling" is observed to be performed in sumps or holding tanks with limited retention times, sporadic removal of suspended solids, and little or no flow control or use of settlig aids. Control of treatment pH is also frequently questionable.

On the basis of the foregoing discussion, the approach to BPT for this subcategory is to provide a single combined treatment system for all process wastewater streams generated (except silver cathodes) within this subcategory. No waste segregation or preliminary treatment of individual waste streams is required, and BPT is limited to treatment technologies presently practiced at a number of plants in the subcategory.

BPT includes some water conservation measures presently demonstrated by most plants practicing each process operation.

In-process control technologies considered to constitute BPT include:

. Recycle or reuse of process solutions used for material deposition and electrode formation.

. Segregation of non-contact cooling and heating water from process wastewater streams.

. Control of electrolyte drips and spills and elimination or recycle of electrolyte equipment wash.

. Use of dry or water efficient floor cleaning procedures.

. Dry clean-up of equipment and floor areas in pasted, pocket or pressed powder cadmium anode production or recycle of equipment and floor wash water.

Identification of BPT

End-of-pipe treatment included in BPT for the cadmium subcategory is presented in Figure IX-1 (Page 738). The treatment system consists of pH adjustment followed by settling. Lime, sodium hydroxide, or acid is used to adjust the pH to a level that permits adequate precipitation. The optimum pH for precipitation of metals from cadmium subcategory waste streams is typically about 9.3; however, higher values may prove to be appropriate for some waste streams in

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this subcategory due to the presence of high concentrations of cadmium and nickel. If proper pH control is practiced, the settling of both metal precipitates and suspended solids will be enhanced. Treatment system performance for some wastewater streams in this subcategory may be significantly enhanced by the addition of iron salts as an aid to the removal of metals, particularly nickel. Where required for acceptable effluent performance, this technique is included in BPT. An effective settling device for use in the BPT system is a clarifier; however similar results can be accomplished by using other settling devices or filtration. In some cases, provision of an oil skimmer may also be required to achieve acceptable effluent quality.

The effectiveness of end-of-pipe technology for the removal of wastewater pollutants is enhanced by the application of water flow controls within the process to limit the volume of wastewater requiring treatment and the pollutants requiring removal. Those controls which are included in BPT are generally applied in the subcategory at the present time, and do not require any significant modification of the manufacturing process or process equipment for their implementation.

CALCIUM SUBCATEGORY

A careful review of collected information characterizing process wastewater and present treatment practices in the calcium subcategory indicates that treatment and control practices are universally inadequate insofar as they do not provide for the reduction of hexavalent chromium or the precipitation of toxic metals prior to discharge. However, there are at present no plants which directly discharge process wastewater from this subcatgory.

The construction of calcium anode thermal cells generates two distinct wastewater streams which differ in their treatment requirements.

The presence of hexavalent chromium, asbestos, and significant quantities of suspended solids in the heat paper production waste stream makes separate treatment of this waste prior to mixing with the wastewater from cell leak testing highly desirable. No in-process control technologies are reported to be employed at these facilities.

On the basis of the foregoing discussion, the approach to BPT for this subcategory is to first provide for segregation of the heat paper process wastewater for reduction of hexavalent chromium, and subsequently to provide combined treatment of both waste streams for the removal of metals. Because most of the pollutants present in the heat paper process wastes (including the hexavalent chromium) are present in the form of particulate solids, removal of these materials by settling prior to the reduction of hexavalent chromium is appropriate. Because the existing technology within the subcategory is

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inadequate, BPT is based on the transfer of technology from other industrial categories.

Identification of BPT

A schematic diagram of the end-of-pipe treatment included in BPT for the calcium subcategory is presented in Figure IX-2 (Page 739). The wastewater from heat paper production is first settled to remove undissolved constituents including zirconium metal, asbestos, and barium chromate. After settling, chemical reduction is provided to convert the remaining hexavalent chromium in the waste stream to the trivalent form which may be effectively removed by precipitation as the hydroxide.

Following reduction of the chromium, the wastewater is combined with wastewater from cell leak testing. The combined stream is treated with lime to precipitate metals and enhance the removal of suspended solids, and is then clarified by settling. Either a clarifier or settling tank may be used, or clarification may be achieved by alternative techniques such as filtration.

The sludge which accumulates during settling must be removed to ensure continued effective operation of the settling device. A vacuum filter is provided in the BPT system to reduce the water content of the sludge and minimize the quantity of material requiring disposal. The resulting filtrate is returned for · further treatment by chemical precipitation and settling.

No in-process control techniques beyond reasonable control of process water use as presently practiced in the subcategory are included in BPT.

LEAD SUBCATEGORY

The identification of BPT for the lead subcategory is based on a careful review of collected information characterizing process wastewater, present treatment practices, and present manufacturing practice. On the basis of this review, it has been concluded that the removal of metals is the primary requirement in treating lead subcategory process wastewater. This may be achieved by chemical precipitation and sedimentation technologies similar to those presently employed at some lead subcategory plants. Unfortunately, these existing treatment facilities in the subcategory were found to be improperly designed, maintained, or operated. In this subcategory, some in-process control techniques which significantly reduce pollutant discharge are commonly practiced and are consequently included in BPT.

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Wastewater from plants in the lead subcategory is characterized by significant concentrations of both lead and suspended solids in addition to smaller concentrations of other metals and oil and grease. The most frequently reported end-of-pipe treatment systems in this subcategory involve pH adjustment and removal of solids. In addition to end-of-pipe treatment, in-process controls contribute significantly to pollutant discharge reduction at many facilities. The recycle of wastewater from pasting operations is particularly effective.

The approach to BPT for the lead subcategory incorporates in-process and end-of-pipe technology. Wastewaters from pasting operations, and spent formation acid are collected separately for reuse (and treatment where required for recycle). The remaining process waste streams are combined for end-of-pipe treatment by chemical precipitation and sedimentation technology. Because this technology is ineffectivly practiced within the lead subcategory at this time, transfer of the technology of proper maintenance and operation from other industrial categories is required.

Identification of BPT

Treatment included in BPT for the lead subcategory is shown in Figure IX-3 (Page 740). The system includes:

1)   Collection and reuse of spent formation acid.

2)   Elimination of process wastewater discharge from paste preparation and application by collection, settling, and reuse.

3)   Treatment of all other process wastewater by chemical precipitation and sedimentation.

The reuse of formation acid, which is common practice among the lead subcategory plants, is conducted by limiting spillage and implementing effective acid collection techniques during postformation dumping. Once the waste electrolyte solution is collected, it is combined with fresh sulfuric acid and water to achieve the acid quality required for process reuse.

The establishment of a closed loop system for the paste processing and area washdown wastewater is a common practice among lead subcategory plants. Settling the wastewater allows for the removal of solids which can be either re-introduced into the paste formulation process or sold to a smelter for recovery of lead. After settling, the wastewater can be either used in paste formulation or pasting area floor and equipment wash-down.

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In the end-of-pipe treatment system for the lead subcategory, caustic, sodium carbonate, or lime is added to a pH of 8.8-9.3 to precipitate lead and any other heavy metals that may be present. In some cases, the addition of sodium carbonate may be required to assist the effective precipitation of lead. A clarifier is the recommended settling device. However, comparable effluent concentrations can be achieved in tanks or lagoons, or by filtration. The resulting sludge should be sent to metal recovery or to a secure landfill.

LECLANCHE SUBCATEGORY

To define BPT for the Leclanche subcategory, the information collected to characterize manufacturing practices, wastewater sources and present treatment and control practices was carefully reviewed. The results of this review indicated that zero discharge is common practice within the subcategory at the present time, and that discharges which presently occur may be eliminated without significant process change by techniques commonly used within the subcategory. Consequently, BPT for this subcategory is to eliminate process wastewater discharge by implementation of in-process treatment and controls.

Process wastewater is generated infrequently at plants in this subcategory, and where it is generated, it is sometimes reused or collected for contract disposal. The wastewater is characterized by significant levels of mercury and zinc as well as TSS, manganese, and oil and grease.

Most plants in the subcategory employ manufacturing processes which generate no process wastewater. At these sites, equipment and production area maintenance are accomplished by dry techniques. Some facilities generate wastewater by washing production equipment and floor areas.

Production equipment which is washed is usually the equipment used to prepare and handle paste separator materials or electrolyte. Contaminants in the resulting waste streams are normal constituents of the paste or electrolyte.

Water is used in some plants to clean the cathode- and anode-making equipment. The resultant wastewater contains electrode materials in the form of suspended solids and may contain oil and grease derived from process machinery lubricants.

Wastewater from paste setting comes from a hot water bath in which the water contacts only the outside of product cells. The water is contaminated only as a result of process malfunctions. Discharge, as described in Section V, is observed to be a matter of operating convenience rather than technical necessity.

On the basis of the foregoing discussion, the approach to BPT for this subcategory is to eliminate sources of process wastewater by implementing alternative operating and maintenance procedures, or by recycling process wastewater. Recycling will generally involve the segregation of process wastewater from individual operations and may require treatment to provide acceptable quality for reuse.

Lithium Subcategory

The identification of BPT for the lithium subcategory is based on a careful review of the information collected to characterize process wastewater and present treatment practices. Individual process waste streams generated in this subcategory may require different treatments and therefore must be segregated for separate treatment prior to or in place of combined waste treatment. Present treatment practices within the subcategory are uniformly inadequate. Consequently, BPT for this subcategory does not provide for combined treatment of all wastewater streams and is based on transfer of technology from other industrial categories.

Wastewater sources identified in the dcp's and follow-up surveys for this subcategory include depolarizer preparation, lithium scrap disposal, heat paper production, cell wash, cell leak testing, and employee clean-up. The characteristics of wastewater from some of these process operations are distinctly different because of the raw materials used. In this subcategory several battery types are manufactured, and the several different wastewater streams are not all associated with one battery type.

The approach to BPT for this subcategory is to provide separate treatments for wastewaters from heat paper manufacture elements, and wastewaters from the production of cells with thionyl chloride and sulfur dioxide depolarizers. The heat paper manufacturing wastewater requires treatment as described for the calcium subcategory for the removal of TSS and reduction of hexavalent chromium. The wastewaters from thionyl chloride and sulfur dioxide depolarizer handling are treated to neutralize acidity, reduce the oxygen demand, and remove TSS. Where they are present together, these individual wastewater streams can be combined with all other wastewaters after the prescribed preliminary treatment. Treatment of combined wastewaters includes chemical precipitation (lime) followed by settling and skimming. Sludge is dried on a vacuum filter and contractor hauled to a secure landfill.

Identification of BPT

End-of-pipe treatment identified as BPT for the lithium subcategory is presented in Figure IX-4 (Page 741). There are three distinct treatment systems for BPT to treat three separate groupings of wastewater

streams generated by this subcategory. Most lithium cell manufacturers do not conduct processes which produce waste streams assigned to all three groups.

The treatment of heat paper waste as shown in Figure IX-4 has previously been described in the calcium subcategory. Metals precipitation treatment is provided in combination with other waste streams as discussed below.

The waste streams associated with the second grouping result from (1) lead iodide depolarizer production, (2) iron disulfide depolarizer production, (3) lithium scrap disposal, (4) cell wash operations, and (5) cell leak testing. The pollutants in this grouping include lead, iron, lithium, oil and grease, and suspended solids. Once these waste streams are combined with the partially treated wastewater from heat paper production, trivalent chromium will become an additional pollutant with various trace contaminants from the heat paper process. The first step in treatment of the combined waste streams is chemical precipitation using lime followed by settling to remove solids. Other reagents including sodium hydroxide, sodium carbonate, or sodium sulfide may be used to achieve similar results if optimum pH conditions are maintained. The recommended settling device is a clarifier with an oil skimming unit for removal of any oil and grease which may be present in the waste stream.

The settled solids are removed from the clarifier, and dewatered in a vacuum filtration unit. The sludge filter cake is disposed of by contractor hauling to secure landfill. Oil and grease removed by the skimming mechanism on the clarifier is contractor hauled. The liquid filtrate from the vacuum filter is recycled back to the treatment system to undergo further treatment.

The third grouping involves waste streams from manufacturing both sulfur dioxide and thionyl chloride depolarizer materials. Initially the wastewater is aerated. This step will reduce the oxygen demand of the wastewater. Sulfuric acid will be formed by oxidation of sulfurous acid. When thionyl chloride is used in the production process, hydrochloric acid will be formed in addition to the sulfuric acid. In either case, the low pH wastewater is neutralized using sodium hydroxide prior to discharge. If lime is used to neutralize the waste stream, precipitates of calcium sulfate and calcium oxide may be present.

Because of the possibility of the formation of precipitates, the neutralized waste stream is passed through a clarifier prior to discharge. The clarifier will also remove any miscellaneous suspended solids contained in the waste streams. Settled solids removed from the clarifier will be removed by contractor hauling to secure landfill.

MAGNESIUM SUBCATEGORY

To define BPT for the magnesium subcategory, the information collected to characterize process wastewater and present treatment practices was carefully reviewed. Wastewater from different process elements within the subcategory differed substantially in treatment requirements. Present treatment practices within the subcategory are uniformly inadequate. Consequently BPT provides separate treatment for segregated waste streams and is based in part on technology transferred from other subcategories.

The processes generating wastewater in this subcategory include depolarizer production, separator processing, heat paper production, and ancillary operations such as cell washing and process area maintenance. The raw materials used in the subcategory process operations vary greatly, which results in distinct waste streams requiring different specific treatments. In this subcategory several battery types are manufactured, and the several different wastewater streams are not all associated with one battery type.

Only two depolarizer manufacturing processes presently conducted in the subcategory discharge wastewater. One facility manufactures cells under dry conditions with vanadium pentoxide as the depolarizer. Wastewater is generated from fume scrubbers associated with the dehumidifier system. The pollutants in the scrubber wastewater may include vanadium pentoxide and lithium chloride. Silver chloride depolarizer material is presently produced using three separate techniques. Two of these techniques generate process wastewater.

One facility makes separators by a process which generates wastewater. Silica glass beads are chemically etched in an ammonium fluoride solution. The resulting wastewater from the etching operation contains both ammonium fluoride and silica particulates.

Pollutant loadings from ancillary operations may include oil and grease, carbon, miscellaneous suspended solids, and various metals found in trace quantities.

The approach to BPT for this subcategory is to provide separate treatment of wastewater streams from some process operations for specific pollutants followed by combined treatment of all wastewater from this subcategory at a given facility for the removal of metals and suspended solids. The wastewater from heat paper production, as described for the calcium subcategory must be initially treated to remove TSS and reduce hexavalent chromium. Wastewater bearing ammonium fluoride require initial treatment for fluoride removal and subsequent aeration together with wastewaters bearing organics from silver chloride cathode surface treatment processes. Because present treatment practice in the subcategory is limited and inadequate,

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technology transferred from other industrial categories constitutes BPT for these wastes.

Identification of BPT

The end-of-pipe treatment included in BPT for the magnesium subcategory is presented in Figure IX-5 (Page 742). Four separate treatment schemes have been developed to handle wastewater from specific process operations. Three of these systems are used to treat wastewater from three separate process operations whereas the fourth removes pollutants from the combined wastewater from a variety of ancillary operations and certain depolarizer preparation processes. The fourth system can be tied to any of the other three systems if any of those systems are required by a given manufacturing facility.

The first system treats wastewater from separator preparation which contains ammonium fluoride and silica particulates. The removal of these pollutants is accomplished in a multi-stage treatment process. In the first treatment operation, fluoride ion is removed from the wastewater by chemical precipitation using lime followed by clarification using settling. The optimum pH for precipitation of the fluoride is 12. The fluoride dissolved in the wastewater will precipitate from solution as calcium fluoride. The ammonia will remain in solution and is subsequently treated by aeration to strip the ammonia into the air. The calcium fluoride precipitate and silica particulates settle out of the wastewater in a clarifier or settling tank. The settled sludge is removed from the clarifier as required, and dewatered in a vacuum filtration unit. The resulting sludge filter cake is contractor hauled to secure landfill.

The second treatment system handles wastewater from the depolarizer preparation process which subjects the silver chloride to an organic photographic developer solution. The resulting product is silver chloride with a metallic silver coating. The processed material is subsequently rinsed and the rinse wastewater is combined with the spent photo developer wastewater stream for treatment. Both of these wastewater streams have similar pollutant parameters. The approach for treating both of these waste streams is to discharge the concentrated organic bath to a holding tank and slowly bleed the tank contents into the rinse wastewater. This practice equalizes the pollutant loads and wastewater concentrations flowing to treatment. It thereby allows effective treatment system operation. In order to reduce the oxygen demand presented by these organic-laden waste streams, the wastewater is aerated. The wastewater generated from heat paper production is treated by the third system which is identical to the treatment described for this waste stream in the calcium subcategory.

All other wastewater streams are treated as combined wastewaters by adjusting the pH to precipitate metals, settling in a clarifier (equipped with an oil skimmer if necessary), and drying the sludge on a vacuum filter. Where segregated wastewaters are treated in the same manufacturing facility, some of the treatment steps can be carried out in the same equipment for more than one stream.

ZINC SUBCATEGORY

A careful review of the information collected to characterize process wastewater and present treatment practices in the zinc subcategory indicates that all of the individual process element waste streams produced can be effectively treated by the same technologies. Appropriate treatment technologies are presently practiced within the subcategory, but they are not found to be properly operated and maintained at the present time. Few plants in the subcategory practice in-process water use controls.

Wastewater from plants in the zinc subcategory is predominantly alkaline as a result of contamination with alkaline electrolytes used in the cells and in electrode processing. The primary pollutants resulting from anode manufacturing processes are zinc and mercury. Pollutants resulting from cathode processes presently used to produce zinc subcategory cells include silver, nickel, manganese, and mercury. In addition, oil and grease and suspended solids are frequently present at substantial concentrations.

Sulfide precipitation, when properly implemented, provides effective removal of most metals including mercury, silver, and zinc. But sulfide precipitation systems observed in this subcategory were not efficiently operated. Amalgamation removes only mercury and, in fact, increases aluminum or zinc concentrations in the wastewater. Mercury removal by amalgamation is observed to be less effective than that achieved by other techniques. Ion exchange and carbon adsorption are both capable of removing a variety of dissolved metals to very low concentrations depending upon the amount of resin or carbon and contact time provided. Mercury effluent concentrations from carbon adsorption units in this subcategory are highly variable. Adjustment of pH and solids removal also provides removal of toxic metals, although effluent levels attainable by this technique are not as low as those reached by sulfide precipitation.

On the basis of these considerations, the approach to BPT for this subcategory is to provide combined treatment for all process wastewater for the removal of metals and TSS. Chemical precipitation-sedimentation-filtration technology presently employed within the subcategory is appropriate as a basis for BPT. However, because of the limitations observed in the present implementation of these technologies within the subcategory, present practice is deemed

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uniformly inadequate, and transfer of proper operation and maintenance from other industrial categories is required. BPT includes only water conservation measures presently demonstrated by most plants practicing each process operation within the subcategory. These may be implemented without any significant change to process equipment or practices.

Identification of BPT

End-of-pipe treatment included in BPT for the zinc subcategory is presented in Figure IX-6 (Page 743). The treatment system consists of pH adjustment, sulfide precipitation, and solids removal by settling in a clarifier and polishing filtration. Lime, sodium hydroxide or sulfuric acid is used to adjust the pH to a level that permits adequate precipitation.

Sulfide precipitation is used based on the fact that mercury sulfide is twelve orders of magnitude less soluble than mercury hydroxide, and lower effluent mercury concentrations are achieved by sulfide precipitation. The reagent used may be either sodium sulfide or iron disulfide. If iron disulfide is used, the iron precipitates as iron hydroxide and is removed with the mercury sulfide. The concentration of iron resulting from the use of iron disulfide in sulfide precipitation will not exceed acceptable levels if proper pH control and solids removal are practiced. After treatment with sulfide, other settling devices or filtration could be used as alternatives to the clarifier.

The final filter is a polishing step for the clarifier effluent. Alternatively, a second clarification stage may be used or, for some plants, the polishing step may prove unnecessary to achieve acceptable treatment levels. The polishing filter which will generally be of mixed media or granular bed construction operated by either pressure or gravity flow.

In addition to end-of-pipe technology for the removal of wastewater pollutants, BPT includes the application of controls within the process to limit the volume of wastewater requiring treatment. Those controls which are included in BPT are generally applied in the subcategory at the present time, and do not require any significant modification of the manufacturing process, process equipment or product for their implementation. They are discussed in detail in Section VII.

In-process control technologies considered to constitute BPT include:

- Recycle or reuse of process solutions used for material deposition, electrode formation, and cell washing.

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- Segregation of non-contact cooling and heating water from process wastewater streams.

- Control of electrolyte drips and spills and elimination or recycle of electrolyte equipment wash.

- Elimination of equipment wash water discharge by reuse or substitution of dry cleaning techniques.

- Control of process water use in rinsing to correspond to production requirements.

As discussed in Section VII, a large number of in-process control techniques could be used in addition to the water use controls specifically identified as BPT. Many of these, including multistage and countercurrent rinses, are presently practiced at plants in this subcategory.

All Wastewater → **pH Adjustment** → **Sedimentation** → Discharge

Sedimentation → Sludge → **Vacuum Filter** → Sludge Hauled

Filtrate → **pH Adjustment**
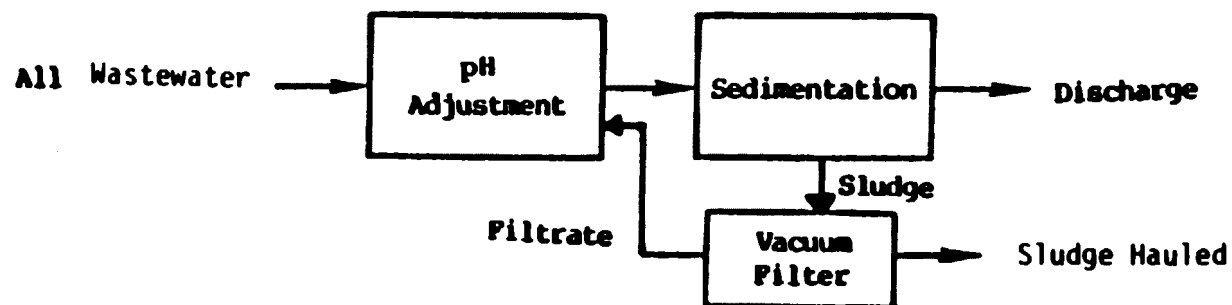
In-Process Technology: Recycle or reuse of process solutions
Segregation of non-contact cooling water from process water
Control electrolyte drips and spills
Use dry methods to clean floors
Use dry method to clean equipment

FIGURE IX-1

CADMIUM SUBCATEGORY
BPT TREATMENT
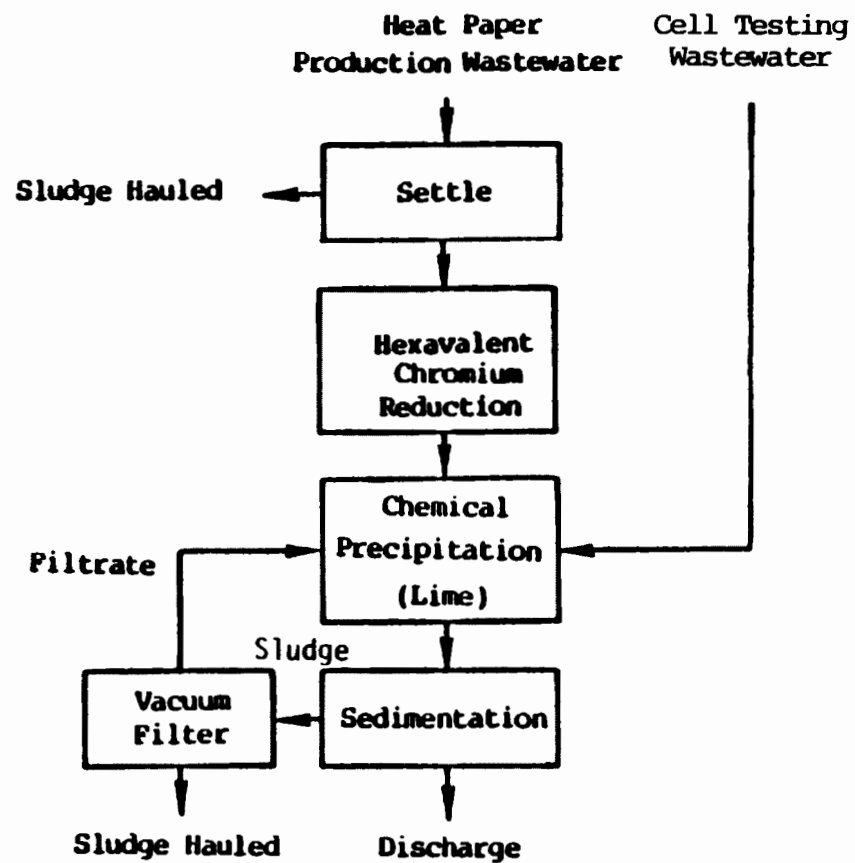
FIGURE IX-2

CALCIUM SUBCATEGORY
BPT TREATMENT

Paste Formulation
And Application
Area Washdown Water → [Multistage Settling] → Recycle or Reuse

[Multistage Settling] → Solids To Paste Formulation

Other Waste
Wastewater → [pH Adjustment] → [Sedimentation] → Discharge

Filtrate

[Vacuum Filter] → Sludge Hauled
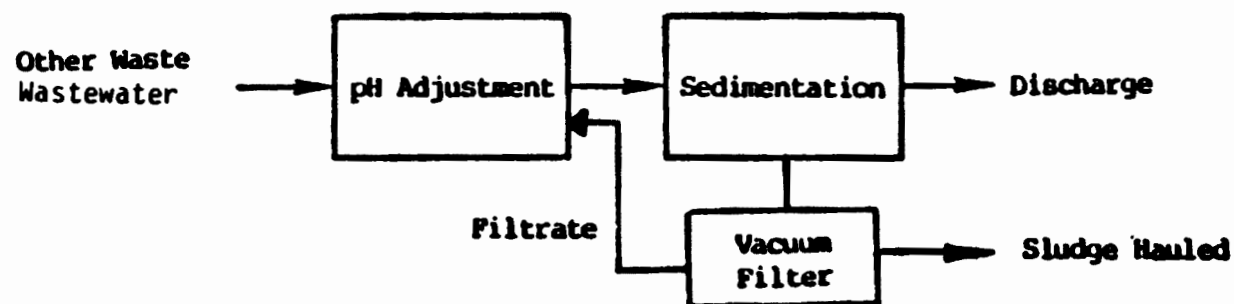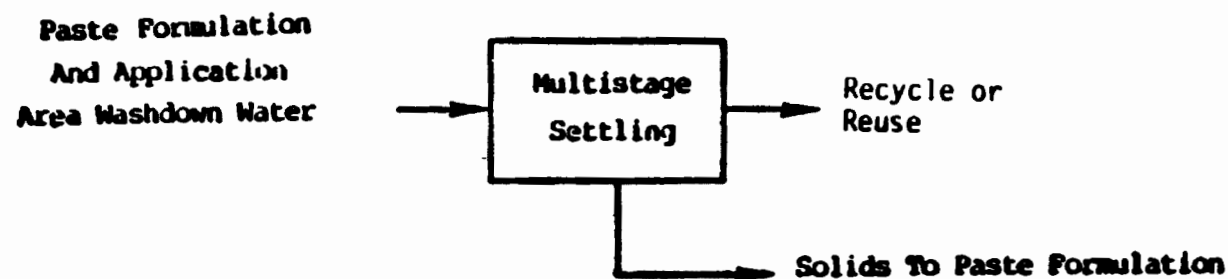
In-Process Technology: Spent formation acid is reused
Pasting operation wastewaters are recycled or reused

FIGURE IX-3

LEAD SUBCATEGORY
BPT TREATMENT

Heat Paper Production
Wastewater
#1

Other Waste
Wastewater
#2

Thionyl Chloride
Sulfur Dioxide Wastewater
#3

Sludge Hauled → **Settle**

Alternate

Aerate

**Hexavalent
Chromium
Reduction**

**Chemical
Precipitation**

**Neutralize
And Settle** → **Sludge Hauled**

**Chemical
Precipitation
(Lime)**

Settle → Discharge

Discharge

Filtrate

Filtrate Sludge

**Vacuum
Filter**

**Settling
(With Skimmer)**

**Vacuum
Filter** → **Sludge Hauled**

Sludge Hauled

Discharge

FIGURE IX-4

LITHIUM SUBCATEGORY
BPT TREATMENT
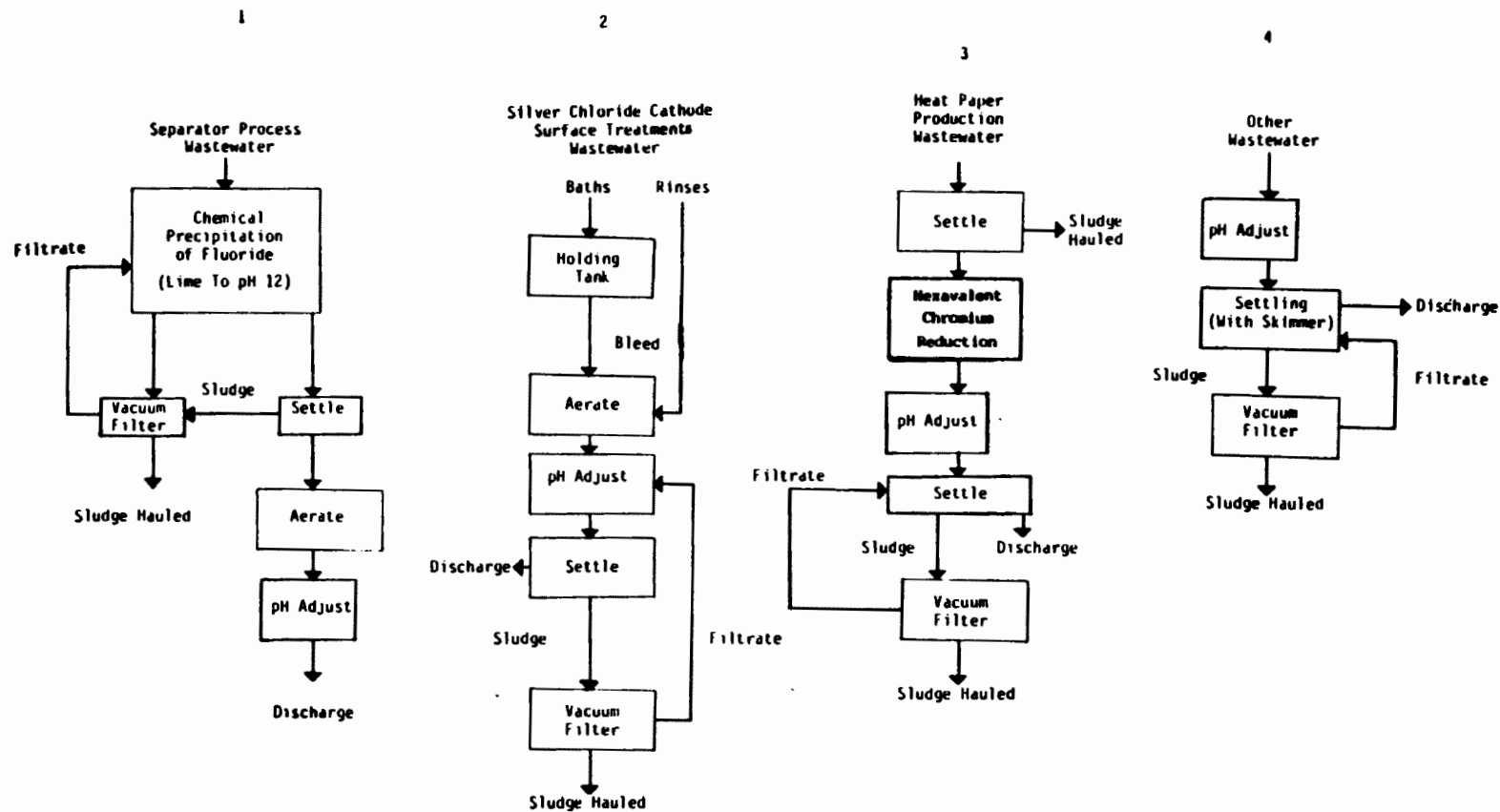
FIGURE IX-5

MAGNESIUM SUBCATEGORY
BPT TREATMENT

Backwash

All Wastewater After
In-Process Water
Reduction

→ pH Adjustment →

Sulfide
Precipitation
And
Sedimentation

→ Filtration → Discharge

Filtrate

Sludge

Vacuum
Filter

Sludge
Hauled
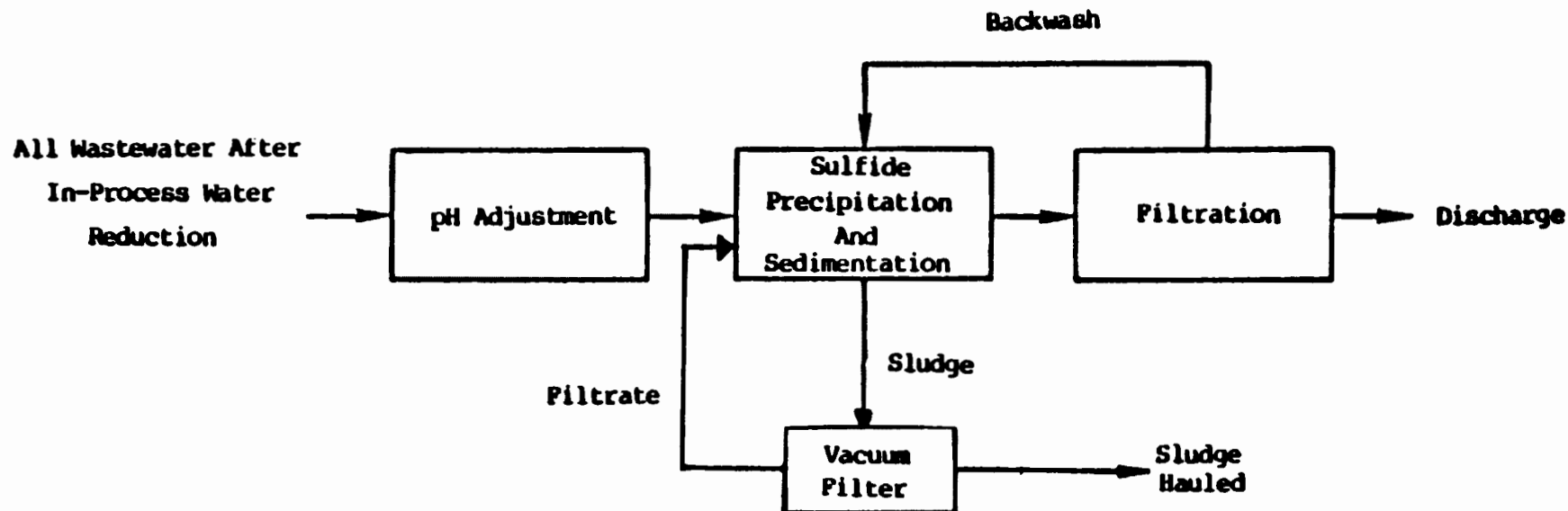
In-Process Technology: Reuse of process solutions
Segregation of non-contact cooling water
Segregation of organic-bearing cell cleaning waste water
.Control electrolyte drips and spills
Eliminate equipment wash water discharge
Flow controls for rinse waters

FIGURE IX-6

ZINC SUBCATEGORY
BPT TREATMENT

SECTION X
BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

[Introductory Note - This section presents the strategy and technical methodology for BAT. Further discussion and the development of regulatory values will be included at proposal]

The factors considered in assessing the best available technology economically achievable (BAT) include the age of equipment and facilities involved, the processes employed, process changes, nonwater quality environmental impacts (including energy requirements), and the costs of application of such technology (Section 304(b)(2)(B)). In general, the BAT technology level represents, at a minimum, the best existing economically achievable performance of plants of various ages, sizes, processes or other shared characteristics. As with BPT, in those subcategories where existing performance is uniformly inadequate, BAT may be transferred from a different subcategory or category. BAT may include process changes or internal controls, even when not common industry practice.

TECHNICAL APPROACH TO BAT

In pursuing effluent limitations for the battery manufacturing category, the Agency desired to review a wide range of BAT technology options and evaluate the available possibilities to ensure that the most effective and beneficial technologies were used as the basis for BAT. To accomplish this, the Agency elected to develop significant technology options which might be applied to battery manufacturing wastewater as BAT. These options were to consider the range of technologies which are available and applicable to the battery manufacturing subcategories, and to suggest technology trains which would make substantial progress toward prevention of environmental pollution above and beyond progress to be achieved by BPT.

In general, three levels of BAT were evaluated for each subcategory. The BAT options considered build on BPT (as described in Section IX), generally providing improved in-process control and end-of-pipe treatment. For two subcategories, BAT options provide for zero discharge of process wastewater pollutants from all process elements. Other subcategory BAT options provide reduced pollutant discharge by reducing both the volume of process wastewater and the concentrations of pollutants, and may include the elimination of wastewater discharge from specific process elements.

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In-Process Control Technology

In-process control technologies included in BAT options were selected based on existing practice within each subcategory or within the battery manufacturing category. Most of the BAT options presented emphasize control of water use and in-process controls contributing to effective water use. These include wastewater segregation, countercurrent rinses, wastewater recycle and reuse, and flow rate controls, in addition to process modifications which are specific to each subcategory. In-process controls which are common to several subcategories are described briefly below. More complete discussions of each have been provided in Section VII.

Waste Segregation - The separation of wastewater streams of distinctly different characteristics is necessary to achieve effective wastewater treatment, recycle or reuse. The segregation of process wastewater from non-contact cooling water is assumed in all BAT options for all subcategories and is essential for the achievement of BAT performance levels. In addition, segregation of specific process wastewater streams to allow recycle or reuse is specified for most subcategories. In some cases, specific wastewater streams are also segregated for separate treatment. Some degree of wastewater segregation is presently practiced by most battery manufacturing plants.

Countercurrent Rinses - Countercurrent rinses, while not common practice in the battery manufacturing category, are encountered at a number of plants in several subcategories.

Wastewater Recycle and Reuse - The recycle of process wastewater to the manufacturing process is an effective means of reducing the volume of process wastewater discharge. Processes in which wastewater recycle is common include wet air pollution control scrubbers and processes where water is used for the physical removal of solid materials (as in lead subcategory electrode pasting for example).

Flow Rate Control - The means of achieving flow rate control include manual valves, automatic shut-off valves, and proportional valves controlled by conductivity, pH, or liquid level sensors.

End-Of-Pipe Treatment Technology

End-of-pipe treatment is provided for the removal of toxic metals by chemical precipitation and of suspended solids (including metal precipitates) by sedimentation and filtration. Different BAT options for each subcategory provide different chemical precipitation or solids removal techniques. For several subcategories, one BAT option uses reverse osmosis technology to significantly reduce the volume of process wastewater which must be treated to remove metals and TSS before discharge.

Specific technologies and approaches to BAT are unique to each subcategory and are considered in the following discussions.

CADMIUM SUBCATEGORY

Four technology options are presented for consideration as BAT for the cadmium subcategory. The first three build upon BPT and represent incremental improvements in pollutant discharge reduction from that technology level. The fourth, based on a system recently implemented at one cadmium subcategory plant, provides zero discharge of process wastewater pollutants.

BAT Option One

The end-of-pipe treatment system selected for BAT-1 is diagrammed in Figure X-1 (Page 766). This system is very similar to that described as BPT, with the addition of sulfide precipitation to improve the removal of dissolved heavy metals. The wastewater is first treated with lime, sodium hydroxide or sulfuric acid to adjust the pH to approximately 10.0. Addition of sodium sulfide or iron sulfide then follows for the precipitation of heavy metals. A clarifier is used to remove suspended solids by settling. Sludge from the clarifier is processed through a vacuum filter. The dewatered sludge is disposed of by a licensed contractor and the vacuum filtrate is returned to the chemical precipitation tank.

Adjustment of the pH to <10 ensures that effective precipitation will be achieved with minimum excess sulfide addition and minimizes the release of hydrogen sulfide. Sulfide precipitation is used because of the significantly lower solubility of metallic sulfides as compared with metallic hydroxides. At the same time, any metal which does not readily precipitate as a sulfide will precipitate as the hydroxide because of the alkaline pH.

In-process controls included in BAT option 1 include:

- Control of rinse flow rates to correspond with production requirements.

- Recirculation of wastewater from wet air scrubber.

- Use of dry cleaning techniques to remove excess deposited material from impregnated electrodes; or recirculation of water used in wet cleaning.

- Reduction of water use in cell washing.

- Countercurrent rinsing of silver powder produced for use in battery manufacturing.

Control of Rinse Flow Rates - The control of rinse flow is important in many process elements within the cadmium subcategory. Flows equal to or less than those reported in dcp's for wastewater discharged from process rinses associated with anode electrodeposition, anode impregnation, nickel cathode electrodeposition and nickel cathode impregnation are attainable by implementation of rinse flow control at all sites. This can be achieved through the use of automatic shut-off valves which close water supply lines when the process is not running, and manual adjustment of rinse flow rates when production rates vary.

Recirculation of Wet Scrubber Wastewater - Wet scrubbers are used in this subcategory to control emissions from electrodeposition, impregnation, and cadmium powder production processes. Because contaminants in the scrubber discharges are dilute, the water can be recirculated through the scrubber. This may require the addition of an alkali to the scrubber stream to neutralize collected acid fumes. Wastewater discharge may be reduced by a factor of 1000 or more by this technique.

Cleaning of Impregnated Electrodes - Both wet and dry cleaning processes are used by plants in this subcategory to remove excess material deposited in the process of impregnating cadmium anodes and nickel cathodes. Dry cleaning can be used to eliminate the wastewater discharge normally associated with wet cleaning. An alternative means of restricting wastewater discharge volume from plants using wet cleaning is to recirculate the water after settling or filtering to remove suspended solids.

Reduction of Water Use in Cell Washing - Three plants in this subcategory presently wash assembled batteries. Water use in this process is presently highly variable. Discharge from zinc subcategory plants employing a similar cell wash process is significantly lower than the cell wash discharge from cadmium plants. Two of the zinc plants currently recycle and reuse this water, and cell wash water use is generally more conservative and more carefully controlled than in cadmium subcategory cell wash operations. BAT-1 limitations for the cadmium subcategory cell wash operations are based on the achievement of discharge flow rates equal to the median flow rate currently discharged from zinc subcategory cell wash operations. This can be accomplished by stringent control of water use, by recirculation of rinse and wash waters, or by the use of multi-stage/countercurrent rinsing techniques.

Countercurrent Rinsing of Silver Powder - Multi-stage countercurrent rinses can be used to reduce wastewater discharge from the production of silver powder. This technique is a proven method of providing high rinsing efficiency while substantially reducing rinse discharge volumes from those from other rinsing techniques.

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BAT Option Two

The end-of-pipe treatment system selected as BAT option 2 for cadmium subcategory wastes is presented in Figure X-2 (Page 767). This system is identical to the system used in BAT-1. pH adjustment and sulfide precipitation are followed by a clarifier for solids removal. Sludge is processed through a vacuum filter. The concentrations of pollutants found in the effluent discharged from end-of-pipe treatment should therefore be similar to that derived from BAT option 1 end-of-pipe treatment. In-process control techniques implemented in BAT-2 significantly reduce wastewater volumes discharged to end-of-pipe treatment, however. As a result, reduced effluent pollutant loadings are attained by application of the complete BAT option 2 treatment and control system.

The in-process control techniques used to effect raw wastewater discharge reductions for BAT option 2 require use of multi-stage countercurrent rinsing. This technique is applied to several different processes in the cadmium subcategory to reduce the amounts of wastewater discharged from product rinsing. BAT option 2 includes the installation of countercurrent rinses in the production of sintered and impregnated anodes, in electrodeposited nickel cathode production, and in cadmium powder production. This requires implementing specific rinse tank modifications for each type of rinse. Several plants in the cadmium subcategory currently utilize continuous multi-stage rinses which can be converted to countercurrent operation with only minor piping changes. Two facilities in this subcategory and a number of plants in other subcategories presently practice countercurrent rinsing.

In-process controls provided in this BAT alternative also include all in-process control techniques applied in BAT option 1 and BPT treatment and control systems.

BAT Option Three

The system designed to treat wastewater discharges in the third BAT alternative for the cadmium subcategory is presented in Figure X-3 (Page 768). This system consists of pH adjustment with lime, caustic or sulfuric acid, followed by filtration to remove suspended solids present in the waste stream. Then the filtrate is treated in a reverse osmosis unit. The reverse osmosis permeate is reused in the process, and the concentrate is treated further by pH adjustment with lime or caustic to raise the pH to approximately 10.0. This is followed by sulfide precipitation and settling in a clarifier or settling tank. The clarifier effluent is then discharged, while the sludge is dewatered in a vacuum filter. The vacuum filter sludge cake is removed for metal recovery or disposal, and the filtrate is returned to the chemical precipitation tank. The concentrate stream

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discharged from reverse osmosis can be effectively treated by sulfide precipitation and sedimentation, ensuring that very low concentrations of toxic metals will be present in the clarified effluent. Other solids removal devices, such as settling ponds, lagoons, granular bed filters or membrane filters could be used in place of a clarifier. The volume of effluent discharged to surface waters from the chemical precipitation system will be greatly reduced in BAT Option 3 compared to the preceeding options because of the process reuse of the RO permeate. Since the concentrations achieved by sulfide precipitation and sedimentation treatment will be the same as in other options, the mass of pollutants discharged is also greatly reduced.

Additional in-process control techniques beyond those provided in BAT options 1 and 2 are also included in BAT option 3 to reduce the wastewater volume and pollutant loads discharged to end-of-pipe treatment. These techniques include:

- Formation of electrodes following battery assembly to eliminate rinses presently associated with electrode formation.

- Effective process control to reduce or eliminate rework in cadmium powder production.

Formation of Electrodes After Cell Assembly - In case formation of sintered and impregnated nickel cathodes was observed in two plants and has the advantage of eliminating discharges from spent formation solutions and post-formation rinses, while not affecting product quality. Since formation is accomplished in the case using the battery electrolyte, it is not necessary to dump the formation electrolyte, and rinsing becomes unnecessary. Electrodeposited cathodes and anodes are formed by operations identical to those used in forming sintered placks and it is concluded that formation of electrodeposited cathodes and anodes after battery assembly is also feasible and this practice is included in BAT option 3.

Improved Process Control in Cadmium Powder Production - BAT option 3 also includes improved control in producing chemically precipitated cadmium powder to ensure complete reaction and efficient rinsing. Improved process and rinse flow control can achieve approximately a 40 percent reduction in wastewater discharge from this process element.

BAT Option 4

The fourth option presented for consideration as BAT for this sub-category is modelled after a system implemented at one plant in the subcategory subsequent to the completion of the data collection phase of this study. This system achieves zero discharge of process wastewater pollutants through a combination of in-process controls,

wastewater treatment, and material recovery techniques as illustrated in Figure X-4 (Page 769).

This option includes:

. The use of countercurrent rinsing and sale of the con- centrated rinse discharge to eliminate wastewater from electrode rinsing operations.

. Treatment of segregated wastewater streams from electrode cleaning by sedimentation and recycle of the clarified water.

. Treatment of all remaining wastewater and recycle of the treated water to process use.

. Distillation of the ion exchange regeneration wastewater and recycle of the condensate to the manufacturing process.

This technology option has been shown to be feasible and economically achievable by its implementation at a cadmium subcategory plant which previously discharged large volumes of process wastewater. However, information about this system became available too late for inclusion in the cost estimates presented in Section of VIII of this draft. Cost information for this option will be included in the proposal development document.

CALCIUM SUBCATEGORY

Two different technology options are presented for consideration as BAT for the calcium subcategory. The first provides improved endof- pipe treatment technology by the addition of polishing filtration to BPT. The second includes segregation, treatment and recycle of the major process waste stream (from the heat paper production) produced in the subcategory and total reuse or recycle of wastewater treated using the same end-of-pipe system specified for BAT option 1. No significant in-process control technologies were identified for inclusion in these BAT options.

BAT Option One

The BAT option 1 treatment system for the calcium subcategory in Figure X-5 (Page 770) is equivalent to BPT with the addition of a polishing filter following chemical precipitation and sedimentation treatment. Two distinct process wastewater streams are treated prior to combination in the chemical precipitation system.

The wastewater stream from heat paper production is passed through a clarifier or settling tank where the suspended material is allowed to settle. The settled sludge is removed periodically and contractor

hauled. Effluent from the settler is treated chemically to reduce hexavalent chromium to the trivalent state prior to chemical precipitation and clarification. Once the heat paper wastewater stream has undergone chemical chromium reduction, it may be combined with the wastes associated with the second wastewater stream.

Wastewater from cell leak testing may contain dissolved metals such as cadmium, nickel, and iron in addition to various trace metal contaminants. The stream may also contain oil and grease and miscellaneous suspended solids which have accumulated on the cell during the various assembly operations. The option 1 treatment system removes the various dissolved metals using chemical precipitation (with lime) followed by clarification of the wastewater stream in a clarifier or settling tank. The settler may also incorporate an oil skimming unit for removal of oil and grease present in the wastewater stream.

The settled solids are removed periodically from the clarifier; and dewatered in a vacuum filtration unit. The sludge filter cake is disposed on a contract haul basis, along with any oil and grease removed by the skimming mechanism on the settler. The liquid filtrate from the vacuum filter is returned to the treatment system to undergo further treatment.

To further reduce the concentrations of metal and suspended solids in the effluent, the waste stream is passed through a multimedia filter prior to discharge. This filter is intended to act as a polishing unit on the treated wastewater stream. Periodic backwashes from the filter are returned to the treatment system.

BAT Level 2

For the calcium subcategory, BAT option 2 treatment includes segregation of heat paper and cell testing wastewater. The cell test wastewater is identical to BAT option 1 treatment, except that following treatment the wastewater is recycled or reused with makeup water added as required. For the heat paper wastewater stream BAT option 2 treatment consists of settling to remove particulate contaminants. The clarified effluent from the settling unit is discharged to a holding tank, from which it is recycled back to the process operation as required. It is intended that all of this wastewater stream be recycled with makeup water added to the system as required. Recycle of this wastewater stream eliminates asbestos and chromium from the effluent discharged from plants in this subcategory. This waste treatment system is illustrated in Figure X-6 (Page 771).

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LEAD SUBCATEGORY

Four distinct technology options are presented for consideration as BAT for this subcategory. These options build incrementally upon BPT and achieve either reduced process wastewater volume or reduced effluent pollutant concentrations in comparison to the previous option. In-process controls included in these options are observed in present practice within the lead subcategory. End-of-pipe technologies transferred from other industrial categories are employed as well as those which are presently practiced at lead subcategory plants.

BAT option 1 combines end-of-pipe treatment identical to BPT with additional in-process control technologies which greatly reduce the volume of process wastewater which is treated and discharged. Option 2 includes the in-process controls provided in option 1 and also provides reduced effluent pollutant concentrations as a result of a change from hydroxides (and carbonates) to sulfides in chemical precipitation. Further reductions in pollutant concentrations are achieved in option 3 by the addition of a polishing filter to the chemical precipitation and sedimentation treatment system of option 2. Finally, option 4 applies reverse osmosis technology to allow the recycle of additional process wastewater, further reducing the volume which is treated in the option 3 end-of-pipe system and discharged.

BAT Option One

The first option for BAT for the lead subcategory combines end-of-pipe treatment identical to that provided at BPT and is shown in Figure X-7 (Page 772) with improved in-process control techniques which significantly reduce the volume of wastewater treated and discharged. In-process controls are included in this alternative to significantly reduce or eliminate process wastewater discharges resulting from the formation of wet or damp batteries, the formation and dehydration of plates for dehydrated batteries, and battery washing. In addition, all in-process control techniques included in BPT are also considered part of this treatment and control alternative. These in-process controls included in BPT eliminate wastewater discharge from plate curing, paste preparation and application, leady oxide production, electrolyte preparation and handling, and general plant clean-up.

Closed Case Formation Discharge Elimination - Wastewater discharges from closed case formation processes are eliminated by application of a variety of in-process control techniques included in this BAT alternative. All are presently observed within the subcategory. At any individual facility, it is unlikely that the implemenation of all of these control techniques will be required, but some subset of these techniques can be combined to eliminate wastewater discharge from these operations at each plant. Specific in-process controls included are:

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. Low rate charging or recycle of contact cooling water

. Recirculation of wet scrubber water

. Control of spillage in electrolyte filling and dumping to reduce case contamination and eliminate battery rinsing, or recirculation of rinse water

Slow charging rates are used in formation to eliminate the use of contact cooling water and the resultant process wastewater discharge. As an alternative to this BAT option 1 control, contact cooling water used in higher rate formation processes may be recycled through a cooling tower and neutralized as required (to prevent corrosion) thus permitting continued use of the water. Widespread practice of these techniques is indicated by the fact that many plants report no process wastewater discharge from contact cooling on formation processes.

Where wet scrubbers are used to control acid fumes and mist resulting from formation processes, recycle of the scrubber water is also required for this level of control. Neutralization of the scrubber water may be required to maintain efficient scrubbing and to limit equipment corrosion.

The use of appropriate technology and reasonable care in filling batteries with acid electrolyte prior to formation limits the extent of acid contamination of the battery cases and of production equipment and work areas. If double fill or fill and dump processes are employed, similar control during the removal of acid from the battery is also required. Production by single-fill techniques simplifies the controls which must be employed since only the single filling operation, and no acid removal operation, must be controlled. Effective control of overflows and acid spillage in filling batteries has been demonstrated, both by manufacturers employing automatic filling equipment (with acid level sensing provisions and special design features to avoid drips and spills) and by manufacturers employing careful manual battery filling procedures. Effective control of spills and overflows during filling is widespread. These practices limit or eliminate the requirement for battery rinsing or washing prior to further handling or shipment, significantly reducing the quantity of wastewater which must be treated. As an alternative to this level of control in filling and acid removal, equivalent pollution reduction may be achieved by combining a lesser degree of control during filling with recycle of the battery rinse water. In some cases, the attainment of a sufficient degree of recycle may require neutralization of the rinse stream.

In all of the instances discussed above where recycle is used to reduce or eliminate wastewater discharges associated with closed case formation processes, the build-up of dissolved salts, and sulfuric

acid may eventually preclude continued recycle and necessitate a bleed from the system. In this BAT option these bleed streams are directed to either the acid cutting or paste preparation processes. Both of these operations have negative water balances and require continual influxes of makeup water. Together, these streams total approximately 0.4 l/kg at a typical lead subcategory plant. This volume of water is consumed in production either as a result of being shipped with the battery as electrolyte or evaporation from the plates during curing and drying. These reuse practices have been observed at existing facilities.

Damp batteries may be a small wet generator of wastewater even with major water use technologies. The normal plant production mix of wet and damp batteries allows ample opportunity to use the wastewater excess from damp batteries.

Plate Formation and Dehydration Discharge Reduction - Significant reductions in process wastewater discharges from the formation and dehydration of plates for dehydrated batteries are achieved by several in-process control techniques provided in BAT. These include:

- Use of countercurrent rinsing and rinse flow control or recycle of wastewater from post-formation plate rinses

- Elimination or recycle of process water used in plate dehydration

- Recycle of wet scrubber water.

Multi-stage, countercurrent rinses and rinse flow control can provide significant reductions in wastewater discharge from rinsing electrodes after open case formation. The extent of reduction achievable is discussed in Section VII. Although countercurrent and multi-stage rinses after open case formation are reported by a number of plants in this subcategory, these are not coupled with effective rinse flow control and consequently generally achieve comparable wastewater discharge volumes to those from single stage rinses. At plants which presently employ rinse flow control, however, the implementation of countercurrent rinses will generally require minimal equipment modifications. As an alternative to countercurrent rinsing and strict rinse flow control, rinse wastewater may be recycled for reuse in product rinsing either before or after treatment. Because this technique affords lower rinsing efficiency than countercurrent rinsing, it may not be compatible with both acceptable product quality and wastewater flow rates at some sites. Also, where wastewater is recycled after treatment, higher treatment costs may be incurred.

Process water used in dehydrating electrodes is from seal water on the vacuum pumps or ejectors used in vacuum drying of electrodes. This

water becomes contaminated with acid and lead from the electrodes and consequently requires treatment prior to discharge. The volume of this wastewater may be greatly reduced by recycle, or eliminated entirely by the use of other dehydrating techniques. These results are achieved by many plants producing dehydrated batteries although most plants did not specifically identify the techniques employed.

Battery Wash Discharge Reduction - In-process control techniques for the reduction of wastewater discharges from battery washing include use of efficient acid addition and removal techniques as discussed previously; use of a rinse to remove most lead and acid prior to washing with detergent formulations. Water use for battery rinsing is minimized by use of countercurrent rinsing; or eliminated by reuse of rinse water for paste formulation. A viable alternative for many facilities is the elimination of battery washing, which eliminates all associated wastewater discharges.

Many plants in the lead subcategory demonstrate the feasibility of the discharge reductions projected by these in-process control techniques and presently discharge little or no process wastewater from battery washing, although specific washing techniques were not generally identified in dcp's. The use of a water rinse prior to detergent washing was observed at a sampled battery manufacturing plant, as was the manufacture of batteries without any battery wash operation.

BAT Option 2

The second option for BAT treatment and control combines in-process control techniques identical to those included in BAT option 1 with improved end-of-pipe treatment providing lower effluent pollutant concentrations. For BAT option 2 the lead subcategory end-of-pipe treatment shown in Figure X-8 (Page 773) consists of pH adjustment with lime or sodium hydroxide and chemical precipitation with sodium sulfide or ferrous sulfide followed by sedimentation in a clarifier or settling tank for solids removal. The treated effluent is discharged and settled solids are removed and dewatered in a vacuum filter. Solids from the vacuum filter are removed for recovery or disposal, and the filtrate is returned for further treatment.

This treatment system differs from that provided in BPT and BAT option 1 by the addition of sulfide precipitation in addition to lime precipitation. Since lead sulfide is much less soluble than lead hydroxide or lead carbonate, improved removal of this pollutant can be achieved. However, the use of sodium carbonate may be advantageous in some instances because the treated effluent from a carbonate precipitation system is compatible with reuse in lead subcategory manufacturing processes whereas the effluent from sulfide precipitation cannot generally be reused in the process. With careful operation, the removal of lead as the basic carbonate can match the effluent per-

formance cited for removal as the sulfide because after precipitation occurs effuent concentrations are primarily governed by solids removal rather than residual solubility.

BAT Option 3

This BAT option includes both in-process controls and end-of-pipe treatment identical to those provided at BAT option 2, but augments the effectiveness of end-of-pipe treatment by incorporationg a polishing filter. The BAT option 3 treatment schematic is shown in Figure X-9 (Page 774). A membrane filter is provided to reduce suspended solids to less than 10 mg/l. Because the sulfides of lead and of other metals are relatively insoluble in alkaline solutions, these metals are present in the effluent from settling primarily as residual precipitate particles. These precipitated particulates will be removed by the membrane filter together with other suspended solids. Consequently, effluent concentrations of these pollutants are also significantly reduced by addition of the membrane filter. A membrane filter has been demonstrated in treating lead subcategory process wastewater on a pilot scale although it was not used in conjunction with sulfide precipitation in that instance.

An alternate BAT Option 3 has been shown as part of BAT Option 3 in Figure X-9 (Page 774). This technology train consists of pH adjustment using lime augmented by carbonate precipitation, settling, and mixed media filtration. The performance of this system should be almost as effective in lead removal as Option 3. This technology train has not been included in cost calculations in Section VIII, but should be substantially less costly than Option 3 because of the lower filter cost.

BAT Option 4

In the fourth alternative for BAT for the lead subcategory, in-process control techniques identical to those included in other BAT alternatives are combined with an end-of-pipe treatment system, shown in Figure X-10 (Page 775). The system provides for neutralization and filtration of the process wastewater after which it is treated by reverse osmosis. The permeate from the reverse osmosis unit is returned to the manufacturing process for use as make-up water, and the concentrate, containing essentially all of the process wastewater pollutants, is treated in a system identical to the end-of-pipe system provided in BAT option 3.

This system allows a significant reduction in the volume of process wastewater released to the environment. Because pollutants are presented to the chemical precipitation process in substantially higher concentrations, treatment effectiveness is significantly increased. While this treatment system is not presently employed

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within the lead subcategory, similar systems are in use in other industries producing process wastewater streams which contain significant concentrations of toxic metals. These systems are reported not only to reduce pollutant discharges but also to reduce the volume of sludge requiring disposal because increased precipitate density is achieved.

LECLANCHE SUBCATEGORY

No BAT options are presented for the Leclanche subcategory because BAT is identical to BPT as described in Section IX.

LITHIUM SUBCATEGORY

Three alternative levels of treatment and control technology are presented for consideration as BAT for this subcategory. Each of these options builds upon BPT, and like BPT, provides somewhat different treatment for each of three distinct wastewater streams generated in this subcategory. All three options incorporate improvements in endofpipe treatment or recycle of treated wastewater. In-process controls providing substantial reductions in process wastewater volumes or pollutant loads have not been identified.

BAT Option 1 achieves reduced effluent pollutant concentrations by the addition of a polishing filter to the chemical precipitation and sedimentation system included in BPT. Option 2 reduces the volume of wastewater discharged by providing for the separate treatment and recycle of heat paper production wastewater. Further effluent volume reduction is achieved by Option 3 through total recycle of wastewater from sulfur dioxide and thionyl chloride handling.

BAT Option One

The BAT option 1 treatment system for the lithium subcategory, shown in Figure X-11 (Page 776), consists of three distinct treatment systems, each of which is directly associated with one of the three major wastewater streams generated by this subcategory.

The first wastewater stream, from heat paper production, is passed through a clarifier or settling tank where the suspended material is allowed to settle. The settled sludge is removed periodically, and disposed of on a contract basis. The effluent from the initial clarifier is treated by chemical reduction to reduce hexavalent chromium to the trivalent state. Once the heat paper wastewater stream has undergone chemical reduction of chromium, it is combined with the wastewater associated with the second major wastewater stream prior to further treatment.

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The combined wastewaters are treated to remove dissolved metals using chemical precipitation (with lime) followed by settling of the wastewater stream by settling in a clarifier. The clarifier may also incorporate an oil skimming unit for the removal of oil and grease. The settled solids are removed from the clarifier, and dewatered in a vacuum filtration unit. The sludge filter cake is disposed of on a contract haul basis, along with any oil and grease removed by the skimming mechanism on the clarifier. The liquid filtrate from the vacuum filter is recycled back to the treatment system to undergo further treatment.

In order to provide improved removal of metals and suspended solids, the clarified wastewater stream is passed through a multi-media filter prior to discharge. This filter is intended to act as a polishing unit on the treated wastewater stream. Periodic backwashes from the filter are recycled back to the treatment system.

The third major wastewater stream is initially aerated to decrease the oxygen demand. In the process, sulfuric acid is formed from the sulfurous acid originally present. Subsequently, the low pH wastewater is neutralized prior to discharge. Lime used to neutralize the waste stream may precipitate calcium sulfate and calcium chloride. Because of the possibility of the formation of precipitates, the neutralized wastewater stream is passed through a clarifier or settling tank prior to discharge. The clarifier also removes miscellaneous suspended solids contained in the wastewater streams. It is expected that solids removed in settling will be disposed on a contract haul basis.

BAT Option 2

For the lithium subcategory, BAT option 2 treatment, shown in Figure X-12 (Page 777), is very similar to BAT option 1 treatment. For the heat paper wastewater stream, however, BAT option 2 treatment consists of settling after which the clarified effluent is discharged to a holding tank, from which 100 percent of this wastewater stream is recycled with makeup water added to the system as required. The BAT option 2 treatment applied to the second major wastewater stream is identical to the system described for this wastewater stream in BAT option 1. Because of the recycle of the treated heat paper wastewater back to the process operation, the BAT option 2 treatment equipment will not be required to remove trivalent chromium from solution.

The BAT option 2 treatment system for the third major wastewater stream is also identical to the system described in BAT option 1.

BAT Option 3

The BAT option 3 treatment system for the lithium subcategory, shown in Figure X-13 (Page 778), is very similar to the system previously

described for BAT 2 treatment. It differs only in that the treated wastewater from thionyl chloride or sulfur dioxide handling is recycled for further process use.

MAGNESIUM SUBCATEGORY

Three different options are presented for consideration as BAT for this subcategory. Each builds upon BPT and provides improved end-of-pipe treatment or recycle of treated wastewater. All of the options presented provide somewhat different treatment for each of four chemically distinct wastewater streams described in Section IX. No significant in-process controls beyond water use controls presently applied in the subcategory are included in any BAT option.

The first BAT option provides end-of-pipe treatment identical to BPT for all wastewater streams, but adds a polishing filter to reduce effluent pollutant concentrations. The second achieves reduced effluent volume by separate treatment and recycle of heat paper production wastewater. The third option achieves reduced pollutant concentrations by providing carbon adsorption treatment for process wastewater streams containing significant organic contaminants.

BAT Option One

The BAT option 1 treatment system for the magnesium subcategory is identical to BPT for this subcategory except that a polishing filter is added prior to discharge of the final treated effluent. It provides four distinct treatment trains as shown in Figure X-14 (Page 779). Three are directly associated with individual wastewater streams generated by this subcategory. The fourth receives wastewater from other process sources.

The first treatment train removes ammonium fluoride and silica particulates in multiple treatment steps. In the first treatment operation, fluoride is removed from the wastewater by chemical precipitation and sedimentation. Lime is added to the wastewater stream to raise the pH of the stream to 12, and the fluoride is precipitated as calcium fluoride. The wastewater is then passed to a clarifier where the calcium fluoride precipitate and silica particulates settle out.

The third wastewater stream, from heat paper production, is passed through a clarifier where suspended material is allowed to settle. The settled sludge is removed periodically from the clarifier and disposed of on a contract hauling basis. The effluent from the clarifier undergoes chemical reduction in order to reduce any hexavalent chromium to the trivalent state prior to chemical precipitation and clarification.

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Each of the above wastewater streams, after the treatment described, and the fourth wastewater stream is individually treated by chemical precipitation, sedimentation, and filtration in order to remove trivalent chromium, silver, and any other metals which may be present in the wastewater. Initially, the pH of the wastewater is raised to 9.0 using lime. The wastewater is then discharged to a clarifier where the precipitates are allowed to settle out of solution. In addition, the clarifier also removes any miscellaneous suspended solids. The clarifier also incorporates an oil skimming unit for removal of any oil and grease which may be present.

The settled solids are removed periodically from the clarifier, with the sludge being dewatered by a vacuum filtration unit. The sludge filter cake is disposed of on a contract haul basis, along with any oil and grease removed by the skimming mechanism on the clarifier. The liquid filtrate from the vacuum filter is recycled back to the treatment system where it undergoes further treatment.

In order to ensure effective removal of metals and suspended solids, the clarified wastewater stream is passed through a multi-media filter prior to discharge. This filter is intended to act as a polishing unit on the treated stream. Periodic backwashes from the filter are recycled back to the treatment system.

BAT Option Two

For the magnesium subcategory, BAT option 2 treatment (shown in Figure X-15 (Page 780)) is identical to BAT option 1 treatment with one exception. For heat paper wastes the clarified (settled) effluent does not undergo chemical reduction. Instead, the treated heat paper waste stream is discharged to a holding tank, from which all of this stream is recycled. Make-up water is added to the system as required.

Because of the recycle of the treated heat paper wastewaters back to the process operation, BAT option 2 treatment equipment will not be required to precipitate and remove chromium from solution.

BAT Option Three

As shown in Figure X-16 (Page 781) the BAT option 3 treatment system for the magnesium subcategory is very similar to the system previously described for BAT option 2 treatment. However, the waste treatment applied to the first and second waste streams is somewhat different from that employed in the BAT options 1 and 2 treatment systems.

As discussed previously, the second major wastewater stream contains a combination of silver, silver chloride, and organic photo developers. In BAT options 1 and 2, the oxygen demand exerted by this waste stream is alleviated by aerating the wastewater. In BAT option 3, this waste

stream is passed through an activated carbon adsorption column. This provides removal of the organics rather than simple reduction of oxygen demand. Once removal of the organics has taken place, the partially treated second wastewater stream is treated in the same way as effluent from the first wastewater stream and the untreated fourth major wastewater stream - treatment for removal of dissolved metals, oil and grease and miscellaneous suspended solids as provided in options 1 and 2.

ZINC SUBCATEGORY

Three technology options are presented for BAT for the zinc subcategory. All three options build upon BPT and provide reduced pollutant discharge by reducing wastewater volumes through the application of in-process control techniques. In addition, two of the options provide augmented end-of-pipe treatment technology.

The first technology option presented for consideration adds in-process control technology to the end-of-pipe treatment provided at BPT, yielding considerably reduced effluent discharge volumes. The second involves additional in-process controls, but also provides improved solids removal in end-of-pipe treatment and reduces both wastewater discharge volumes and pollutant concentrations. The third option retains chemical precipitation and solids removal technologies identical to those provided at BPT but minimizes wastewater discharge volumes by the application of in-process control beyond those provided in option two and by inclusion of reverse osmosis and treated wastewater recycle in the end-of-pipe system.

BAT Option One

This alternative combines end-of-pipe treatment technology identical to that provided for BPT with improved in-process control practices to reduce the volume of wastewater which is treated and discharged. End-of-pipe treatment provided at this level, as shown in Figure X-17 (Page 782), includes pH adjustment, sulfide precipitation, settling for suspended solids removal, and polishing treatment in a multi-media granular bed or equivalent filter. Water use control techniques included in BPT as discussed in Section IX are also included in this treatment and control alternative.

In addition to BPT treatment and control practices, this alternative includes a number of in-process control techniques to reduce the volume of wastewater and mass of pollutants presented to the end-of-pipe treatment system. These include:

- Countercurrent rinsing of wet amalgamated zinc powder to reduce the volume of this mercury contaminated waste stream.

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- Treatment and recirculation of water used to wash amalgamation area floors.

- Use of a multistage countercurrent rinse after formation of zinc anodes.

- Countercurrent rinsing of silver powder produced by electrolytic deposition.

- Use of countercurrent rinses after formation of silver oxide cathodes.

- Control of rinse flow rates and countercurrent rinsing of silver peroxide produced by chemical oxidation.

- Control of water use in equipment and product rinsing in silver peroxide cathode production. Use of countercurrent rinsing or wastewater recirculation to effectively limit wastewater discharges.

- Control of impregnated nickel cathode wastewater discharges as specified in BAT option 1 for the cadmium subcategory.

- Use of countercurrent rinses or rinse water recycle in cell washing.

- Countercurrent rinsing after silver etching operations to prepare electrode support grids.

- Use of dry cleanup techniques for general plant floor areas, or complete recycle of floor wash water.

Countercurrent Rinsing and Water Flow Control - Rinsing electrodes and active materials for use in electrodes accounts for most of the process wastewater discharged from this subcategory. As discussed in Section VII, a variety of techniques including water use control, multi-stage rinsing, countercurrent rinsing, and wastewater recycle and reuse are applicable to the reduction of the volume of wastewater discharged from this source. Countercurrent rinsing, when combined with effective control of rinse water flow rates, provides the lowest discharge volumes attainable without an adverse effect on rinsing effectiveness. Multistage rinsing is frequently practiced at present although it is rarely combined with effective control of rinse flow rates. Equipment presently in place for multi-stage rinses will frequently allow the implementation of countercurrent rinses with little additional investment and little or no requirement for additional floor space.

Amalgamation Clean-Up Discharge Elimination - Water used in washing amalgamation area floors becomes contaminated with mercury as well as zinc and suspended solids. Recycle of this water for continued use in floor washing is possible if the mercury is removed by treatment prior to recycle. This may be accomplished using sulfide to precipitate mercury sulfide prior to removal of suspended solids. When the sulfide is added in the form of ferrous sulfide, effective precipitation is achieved and mimimum levels of residual sulfide ion result. An alternative in-process control technique which eliminates process wastewater discharge from this source is the substitution of a totally dry amalgamation process. In these

BAT Option Two

End-of-pipe treatment technology and in-process control techniques are augmented in this alternative to provide lower pollutant discharges than are attained by BAT option 1. Consequently, the effluent flow rate and pollutant concentrations are reduced as a result of implementing this level of treatment and control.

End-of-pipe treatment provided in this alternative is similar to that provided for BPT and BAT option 1 except that a membrane filter is used for polishing filtration in place of the multi-media filter included in the two previous levels of treatment. This end-of-pipe treatment system is shown in Figure X-18 (Page 783). Because metals are present primarily as solids after sulfide precipitation, improved TSS removal provides lower effluent concentrations of many metals.

In-process control techniques included in this alternative for BAT include all of the controls cited for BAT option 1, plus four additional measures.

- In wet amalgamation processes, separate treatment of product rinse wastewater using ferrous sulfide and settling, and use of the resultant treated stream for floor washing in place of makeup water.

- Elimination of all wastewater discharge from gelled amalgam processes, by process modification to eliminate water use.

- Treatment of segregated wastewater from silver peroxide production by reverse osmosis (RO) and reuse of the RO permeate; or process modification to allow direct reuse of process solutions.

- Elimination of the use of chromates in cell washing.

BAT Option Three

This alternative for BAT combines in-process control techniques simi-
lar to those included in BAT option 2 with an end-of-pipe treatment
system which permits the recycle of a substantial part of the waste-
water discharged to treatment. Recycle is made feasible by use of a
reverse osmosis unit.

End-of-pipe treatment included in the BAT alternative as shown in
Figure X-19 (Page 784) includes pH adjustment, filtration, and reverse
osmosis. The permeate from the RO unit is returned to the process
where it may be used in place of fresh makeup water. The RO
concentrate stream is treated by pH adjustment, sulfide precipitation,
settling and multimedia filtration, and subsequently discharged.
Treated wastewater is used to backwash the multi-media filter, and
the filter backwash is returned to the clarifier or settling tank.
Solids settled from the wastewater are dewatered in a vacuum filter or
equivalent device and the filtrate is returned to the treatment
system.

The implementation of this end-of-pipe system results in the presen-
tation of a low flow of concentrated wastewater stream to the chemical
precipitation process since most of the wastewater permeates the RO
membrane and is returned to the process. As a result, the mass of
pollutants discharged is reduced. The feasibility and effectiveness
of reverse osmosis in this application is demonstrated by its
successful use under similar circumstances in other industries.

In-process control techniques in this option include process modi-
fication to perform all amalgamation by dry processes producing no
process wastewater discharges, formation of nickel cathodes after cell
assembly as discussed for the cadmium subcategory, and all the in-
process control techniques included in BAT option 2. These techniques
combine to significantly reduce the volume of process wastewater
flowing to end-of-pipe treatment, to increase the treatability of the
wastewater, and to eliminate cyanide and hexavalent chromium from
process wastewater discharges in this subcategory.

Process modification to replace wet amalgamation with dry amalgamation
has been demonstrated at one plant where this process substitution had
been partially accomplished at the time of on-site data collection and
sampling. The amalgam produced by the two processes was reported to
be interchangeable.
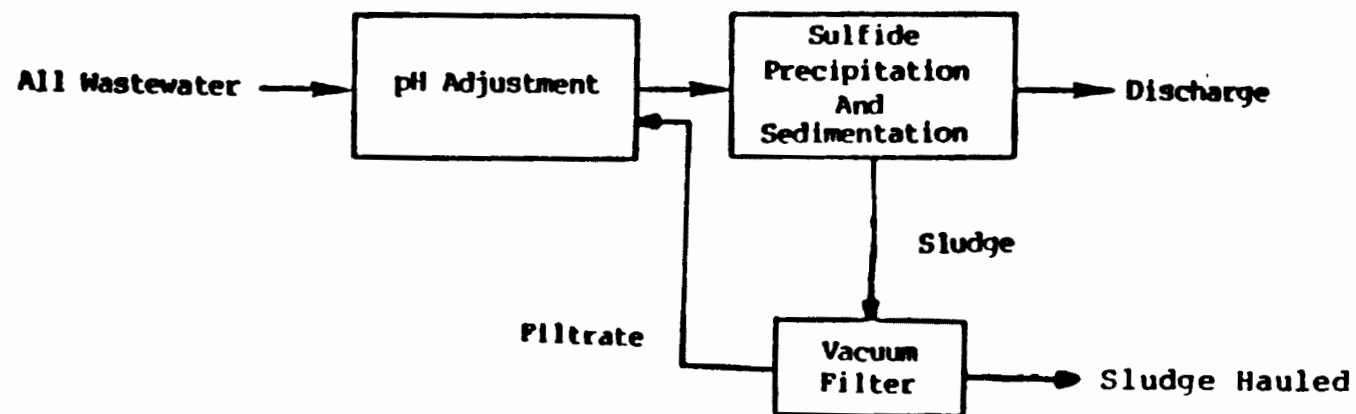
Additional In-Process Technology: Control rinse flow rates
Recirculate wastewater from air scubber
Dry clean impregnated electrodes
Reduce cell wash water use
Countercurrent rinse silver powder

FIGURE X-1

CADMIUM SUBCATEGORY
BAT OPTION 1 TREATMENT

All Wastewater
After In-Process → pH Adjustment → Sulfide Precipitation And Sedimentation → Discharge
Water Reduction

Sludge

Filtrate

Vacuum Filter → Sludge Hauled
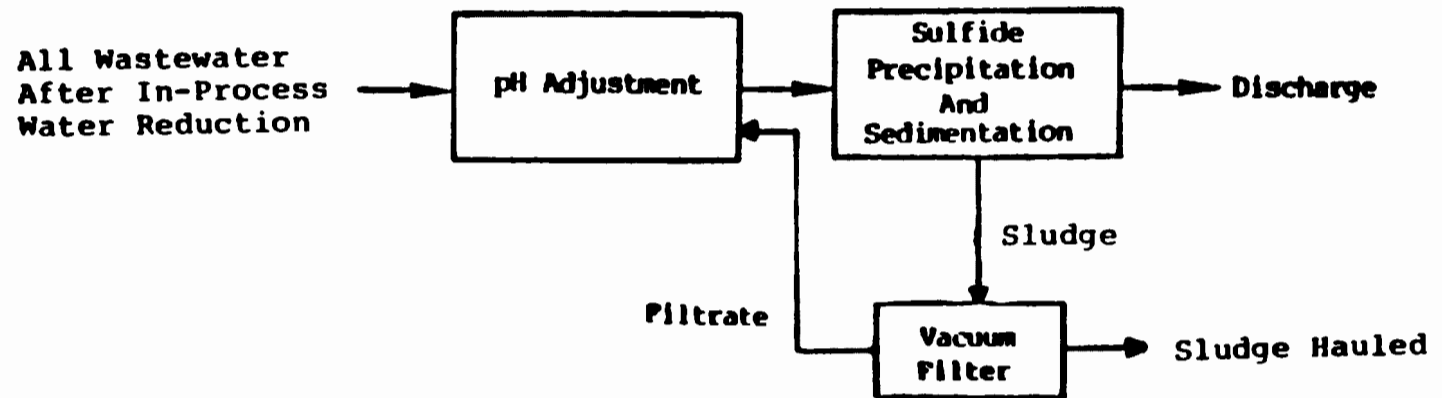
Additional In-Process Technology:
    Countercurrent rinse for
    sintered and impregnated
    anodes, electrodeposited nickel
    cathodes, cadmium powder

FIGURE X-2

CADMIUM SUBCATEGORY
BAT OPTION 2 TREATMENT

All Wastewater After
In-Process Water
Reduction

→ pH Adjustment → Filtration → Reverse Osmosis → Reuse

Filtration → Sludge Disposal

Reverse Osmosis → Concentrate → pH Adjust

pH Adjust → Sulfide Precipitation And Sedimentation → Discharge

Sulfide Precipitation And Sedimentation → Sludge → Vacuum Filter

Vacuum Filter → Sludge Hauled or Reclaimed

Filtrate

Additional In-Process Technology: Form electrodes in cells
Reduce cadmium powder rework

FIGURE X-3

CADMIUM SUBCATEGORY
BAT OPTION 3 TREATMENT
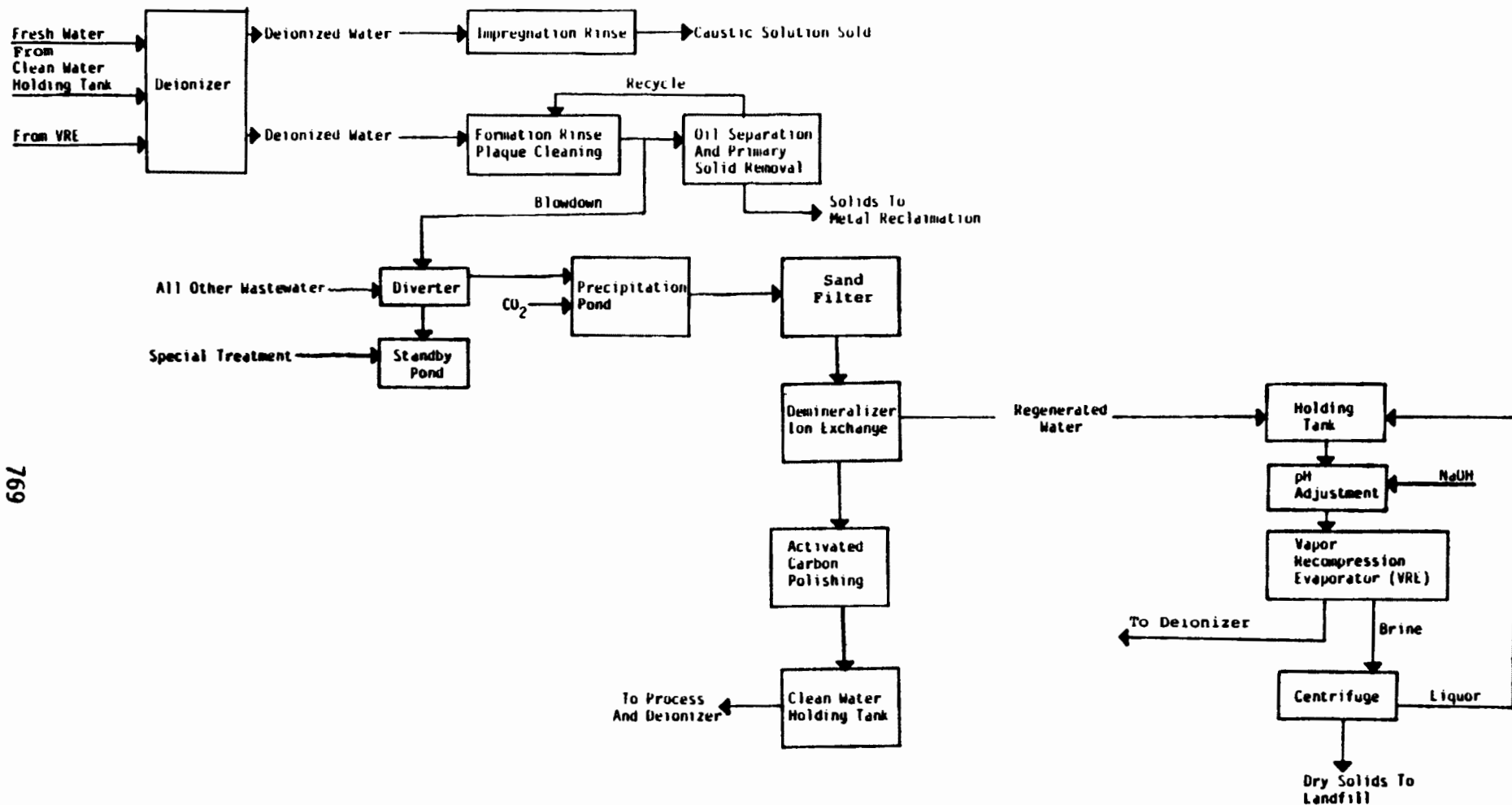
Figure X-4

CADMIUM SUBCATEGORY
BAT OPTION 4 TREATMENT

Heat Paper
Production Wastewater

Cell Testing
Wastewater

Settle → Sludge Hauled

Hexavalent
Chromium
Reduction

Filtrate

Chemical
Precipitation
(Lime)

Vacuum
Filter ← Sedimentation

Sludge Hauled

Polishing
Filter
(Multimedia)

Discharge

In-Process Technology: None specified

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FIGURE X-5

CALCIUM SUBCATEGORY
BAT OPTION 1 TREATMENT

Cell Testing
Wastewater

Heat Paper
Production Wastewater

Filtrate

Chemical
Precipitation
(Lime)

Settle

Return To
Process

Vacuum
Filter

Settle

Holding
Tank

Sludge Hauled

Polishing
Filter
(Multimedia)

Backwash

Return To Process
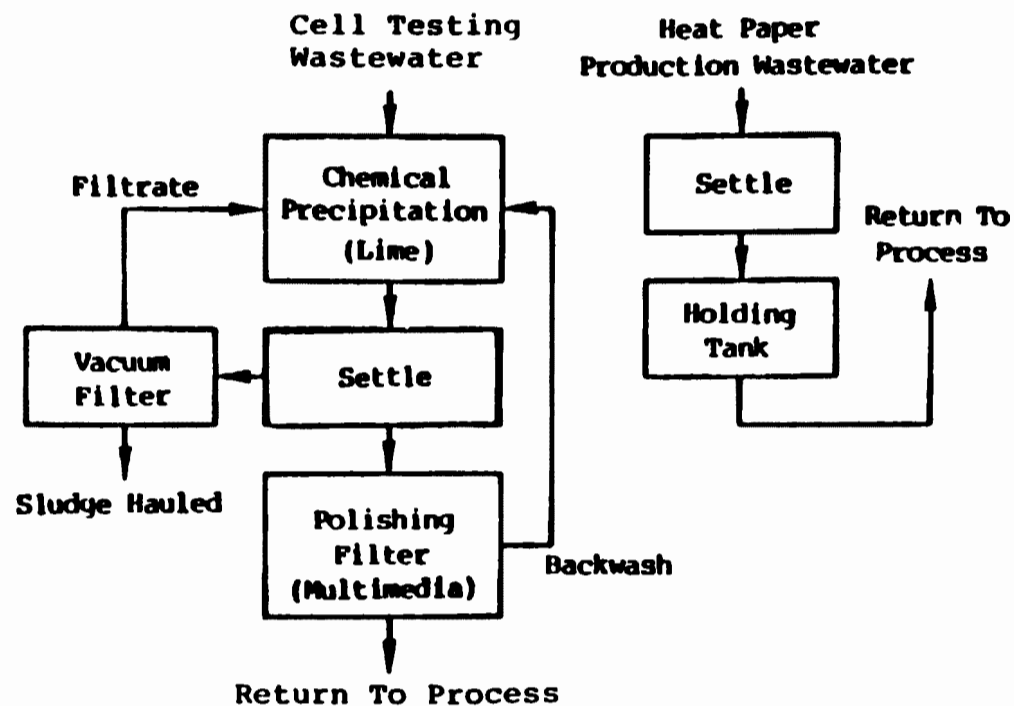
In-Progress Technology: None specified

FIGURE X-6

CALCIUM SUBCATEGORY
BAT OPTION 2 TREATMENT

Paste Formulation
And Application
Area Washdown Water ⟶ **Multistage Settling** ⟶ Reuse or Recycle

⟶ Solids To Paste Formulation

Other Wastewater
After In-Process ⟶ **pH Adjustment** ⟶ **Settling** ⟶ Discharge
Water Reduction

Vacuum Filter ⟶ Sludge Hauled

Filtrate
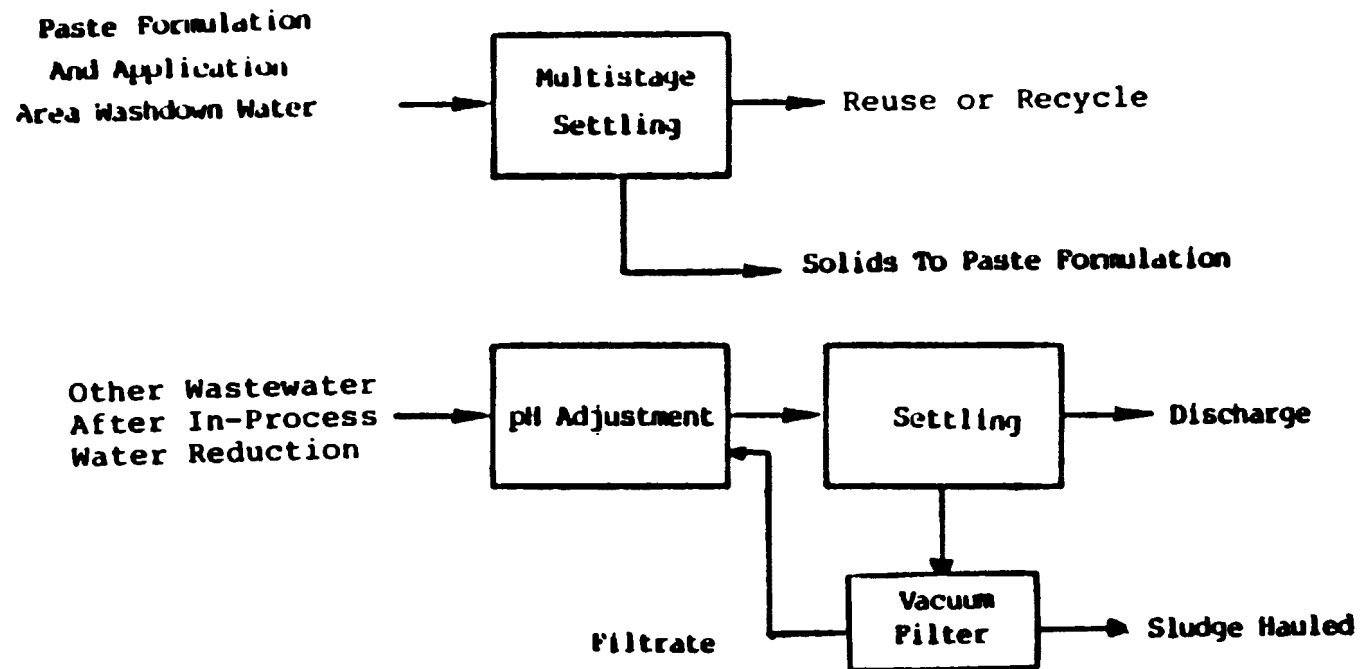
Additional In-Process Technology: Low rate charge in case
Recirculate air scrubber water
Control spills
Countercurrent rinse electrodes after formation
Eliminate process water for plate dehydration
Water rinse of batteries prior to detergent wash
Countercurrent rinse batteries or reuse battery rinse water

FIGURE X-7

LEAD SUBCATEGORY
BAT OPTION 1 TREATMENT

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Paste Formulation and
Application Area
Washdown Water → [Multistage Settling] → Reuse or Recycle

→ Solids to Paste Formulation

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→ Sludge Handling

Battery Wash and
Dehydrated Plate
Rinse Wastewater → [pH Adjustment] → [Sulfide Precipitation and Sedimentation] → Discharge

Filtrate

[Vacuum Filter] → Sludge Hauled

Additional In-Process Technology: None
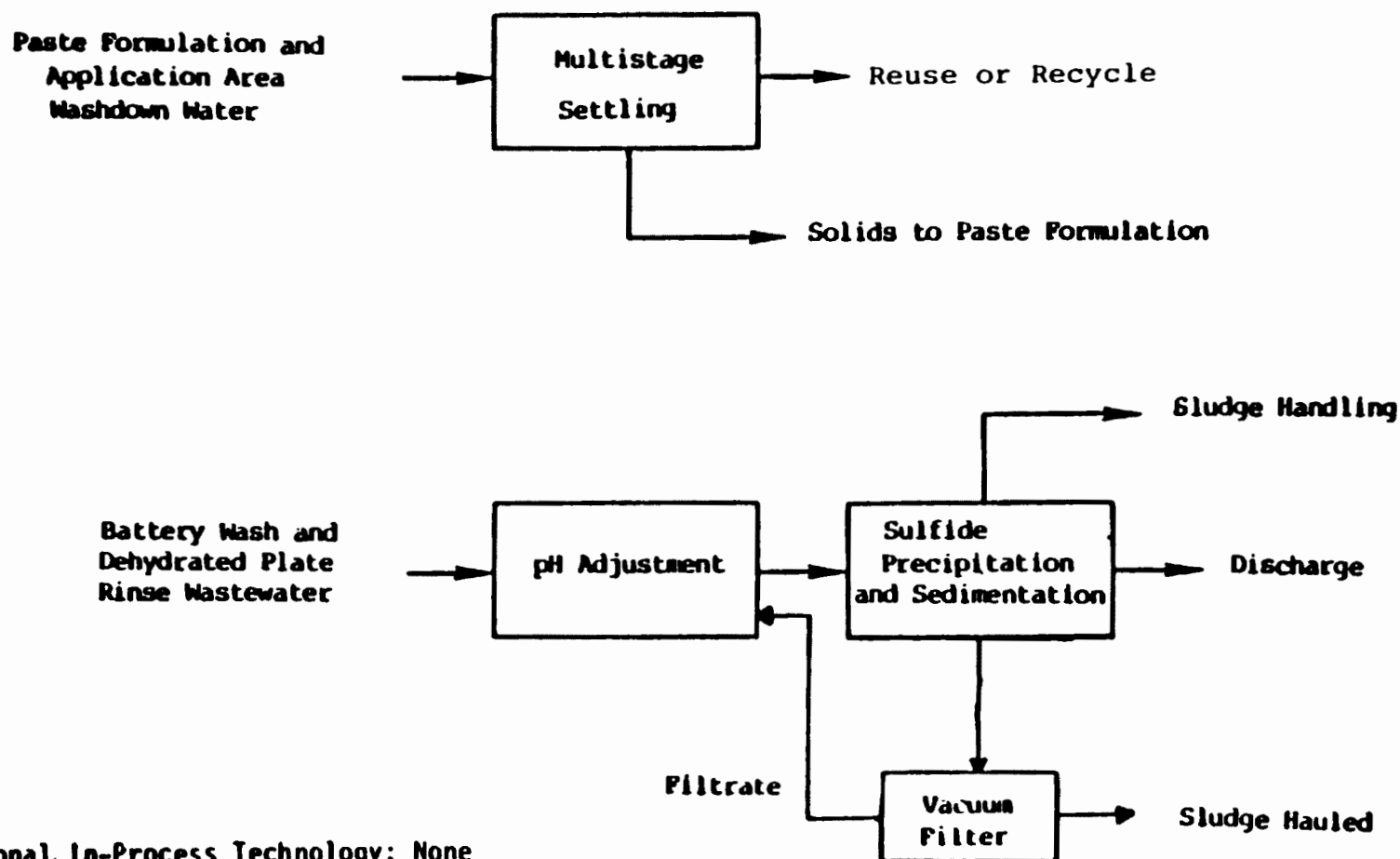
FIGURE X-8

LEAD SUBCATEGORY
BAT OPTION 2 TREATMENT
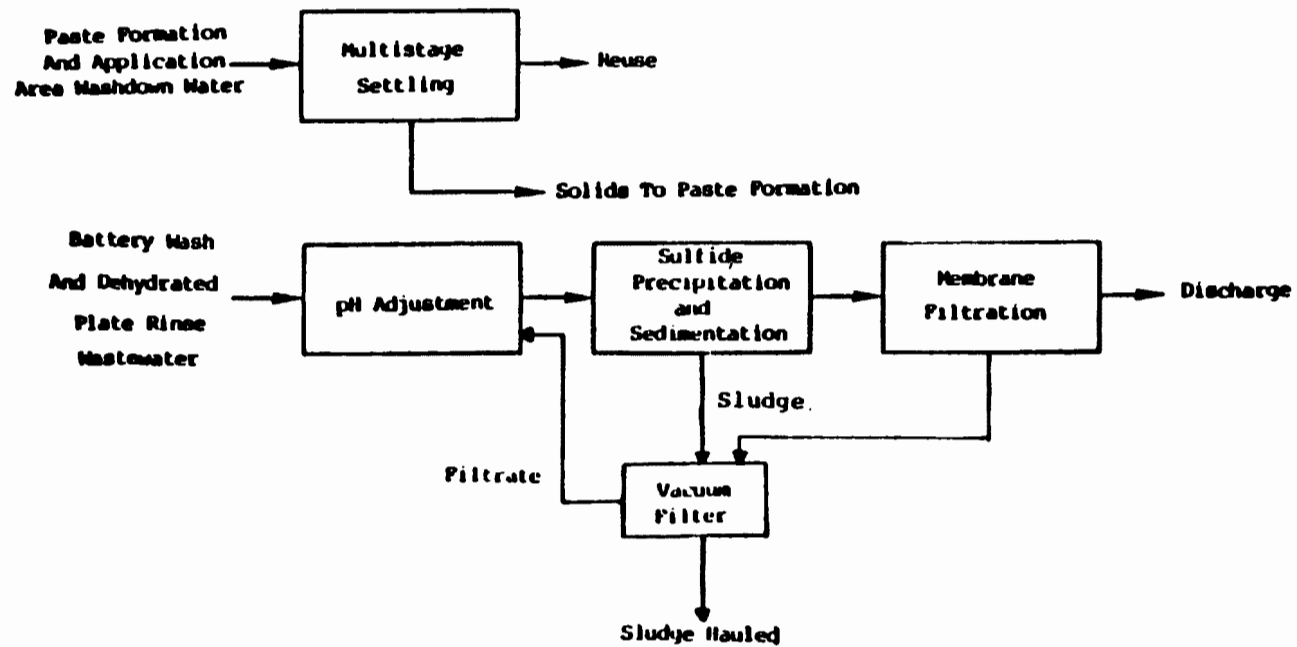
Option 3 Alternate
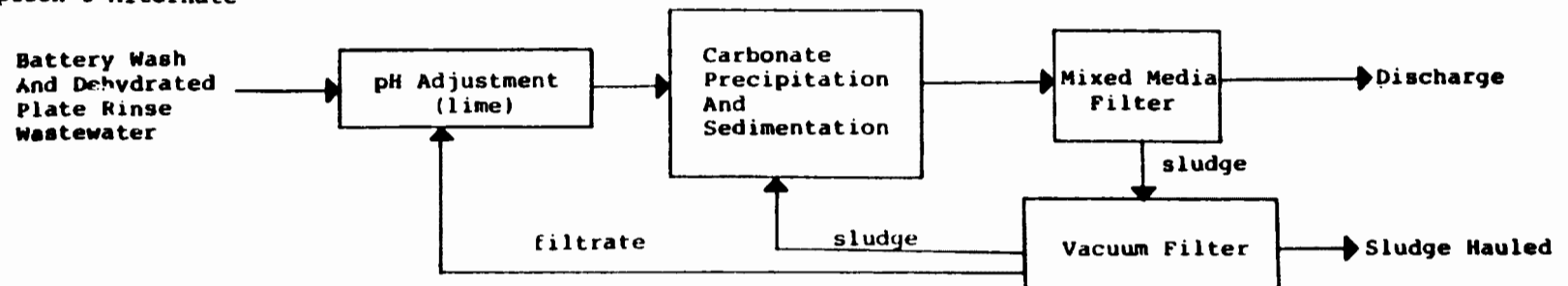
Additional In-Process Technology: None

FIGURE X-9

LEAD SUBCATEGORY
BAT OPTION 3 TREATMENT

Paste Formulation
and Application
Area Washdown
Wastewater

Recycle

Multistage
Settling

Lead Oxides

Return To Process

Recycle To Process ◄—— Permeate

Battery Wash

Dehydrated Plate

Rinse

pH Adjust

Filter

Reverse
Osmosis

Back Wash

Brine

Sulfide
Precipitation
& Settling

Membrane
Filter

Discharge

To Use In Backwashing
Filters

Filtrate

Vacuum
Filter

Additional In-Process Technology: None

Sludge Hauled
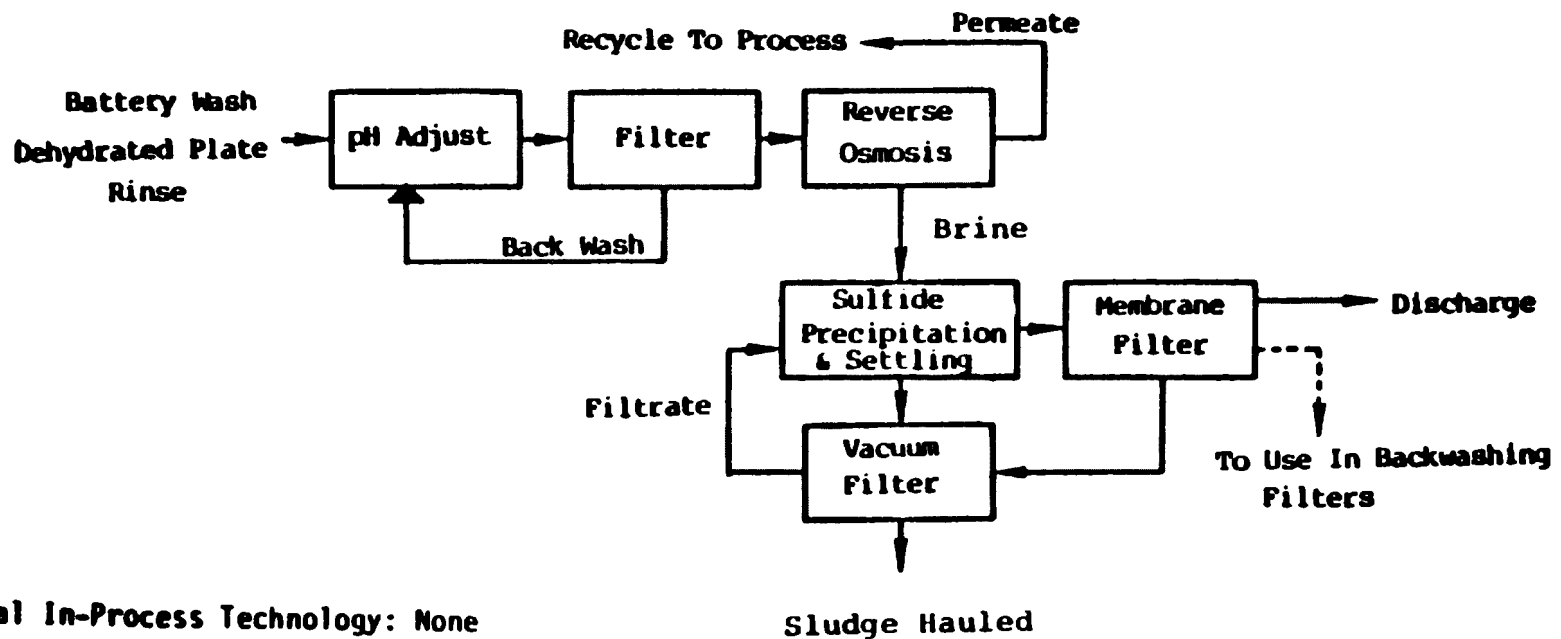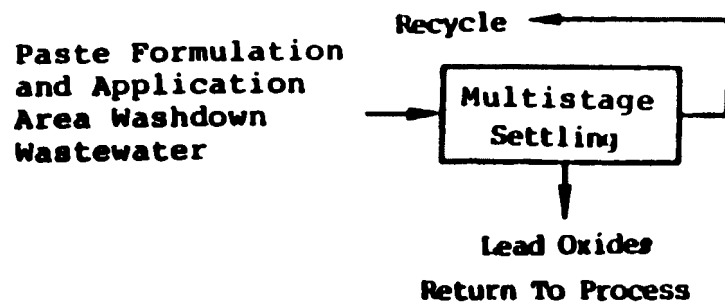
FIGURE X-10

LEAD SUBCATEGORY
BAT OPTION 4 TREATMENT

775
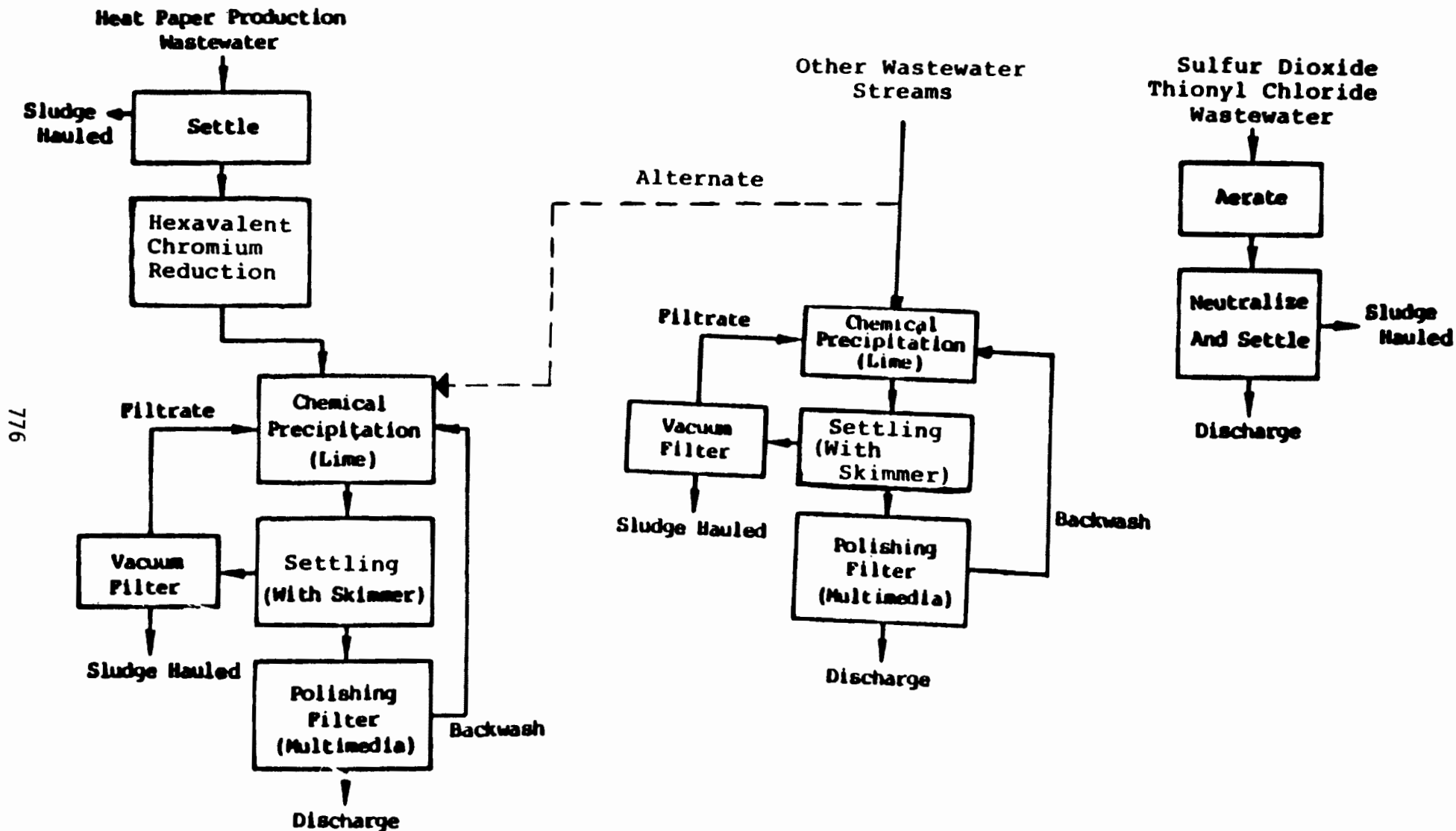
FIGURE X-11

LITHIUM SUBCATEGORY
BAT OPTION 1 TREATMENT

Heat Paper Production
Wastewater

Other Wastewater
Streams

Sulfur Dioxide
Thionyl Chloride
Wastewater

Sludge
Hauled ← Settle → Return To
Process

Filtrate → Chemical
Precipitation
(Lime)

Aerate

Holding
Tank

Vacuum
Filter ← Settling
(With Skimmer)

Neutralize
And
Settle → Sludge
Hauled

Sludge Hauled

Polishing
Filter
(Multimedia) → Backwash

Discharge

Discharge
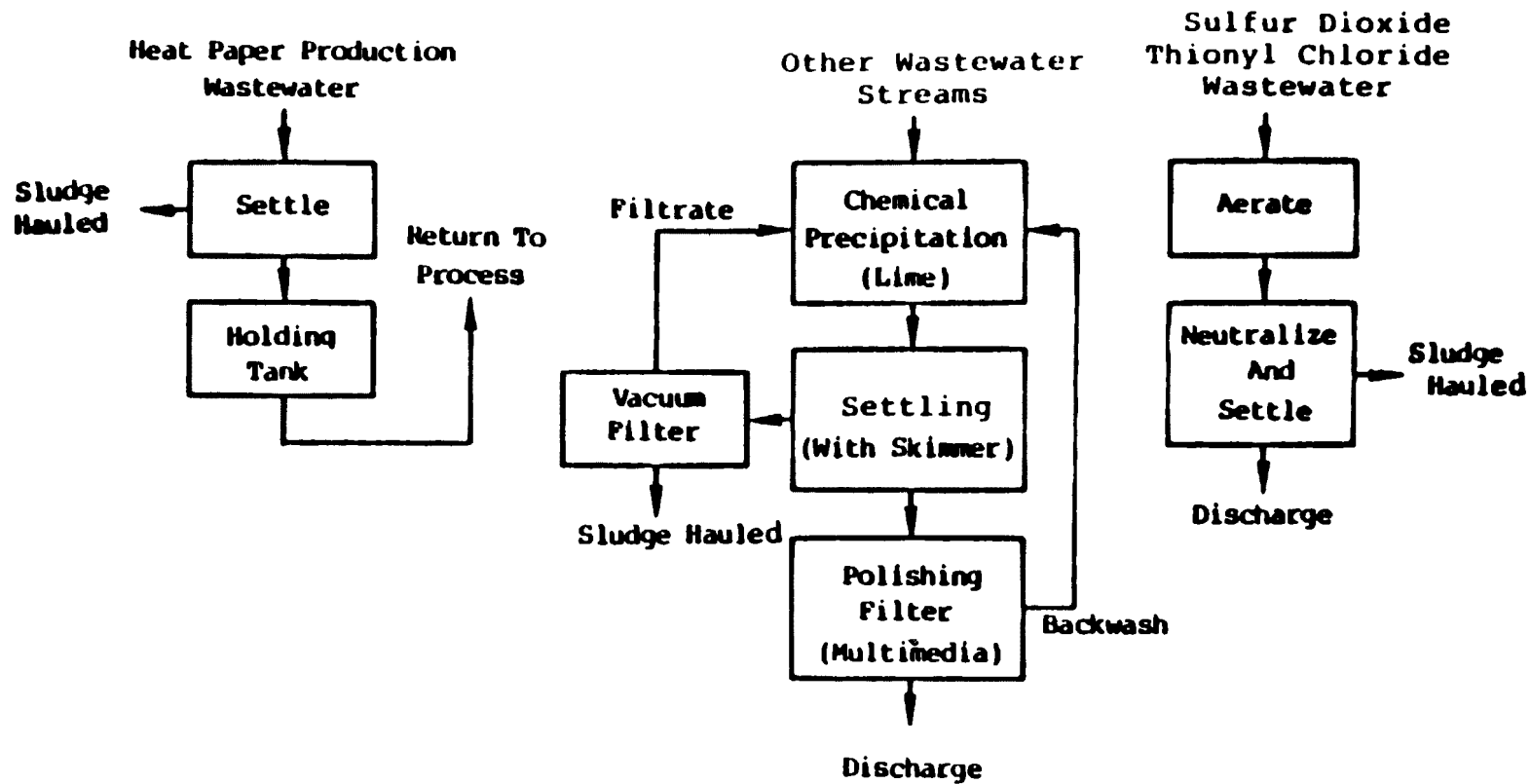
FIGURE X-12

LITHIUM SUBCATEGORY
BAT OPTION 2 TREATMENT

777

Heat Paper Production
Wastewater

Other Wastwater
Streams

Sulfur Dioxide
Thionyl Chloride
Wastewater

Sludge
Hauled — Settle

Return To
Process

Holding
Tank

Filtrate → Chemical
Precipitation
(Lime)

Vacuum
Filter → Settling
(With
Skimmer)

Sludge Hauled

Polishing
Filter
(Multimedia)

Backwash

Discharge

Aerate

Return To
Process

Neutralize
And Settle → Sludge
Hauled

Discharge
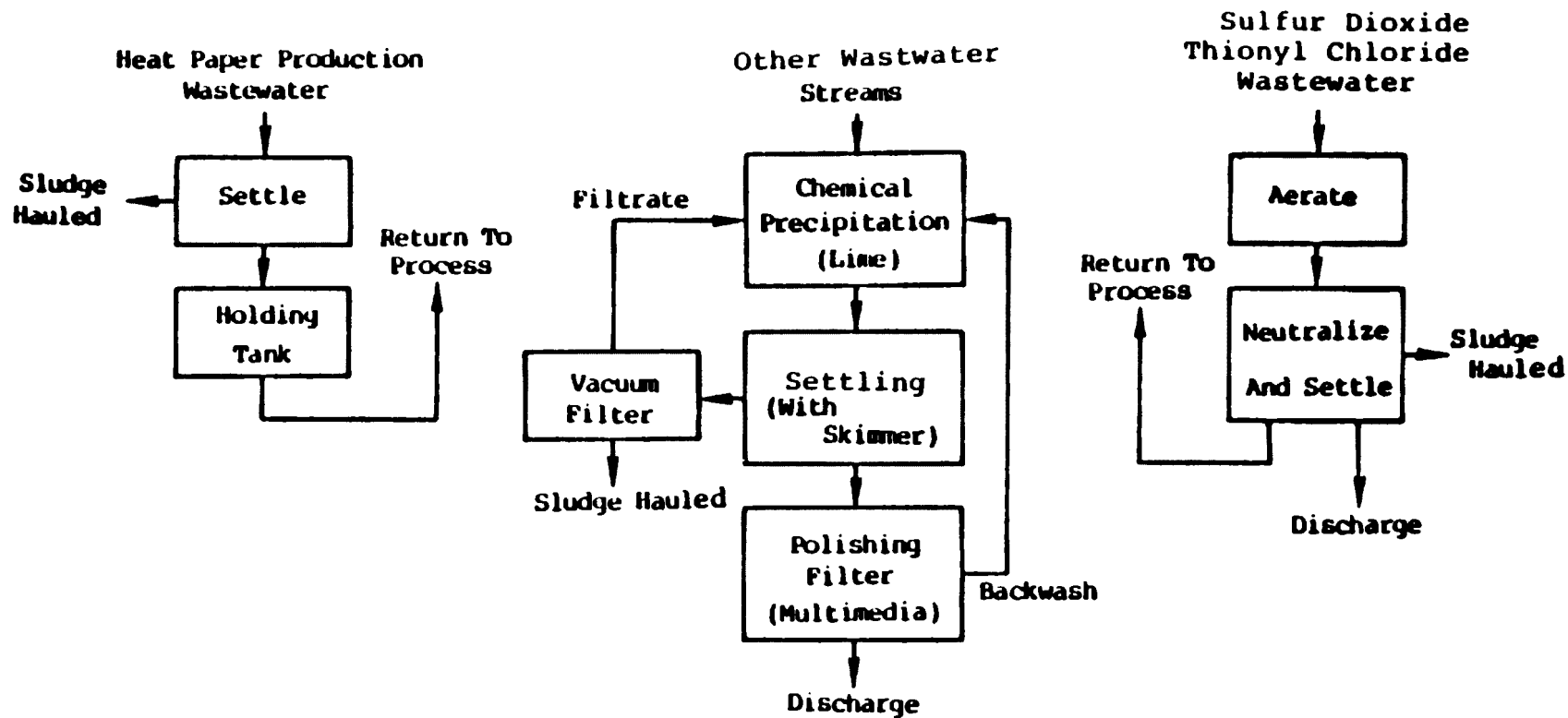
FIGURE X-13

LITHIUM SUBCATEGORY
BAT OPTION 3 TREATMENT

Separator Process
Wastewater

Chemical
Precipitation
of Fluoride
(Lime To pH 12)

Filtrate

Vacuum
Filter

Sludge

Settle

Sludge Hauled

Aerate

pH Adjust

Settling

Polishing
Filter
(Multimedia)

Backwash

Discharge

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Silver Chloride Cathode
Surface Treatments
Wastewater

Baths   Rinses

Holding
Tank

Bleed

Aerate

Backwash

pH Adjust

Polishing
Filter
(Multimedia)

Settle

Sludge

Discharge

Vacuum
Filter

Filtrate

Sludge Hauled

Heat Paper
Production
Wastewater

Settle

Sludge
Hauled

Hexavalent
Chromium
Reduction

Backwash

pH Adjust

Polishing
Filter
(Multimedia)

Settle

Sludge

Vacuum
Filter

Filtrate

Discharge

Sludge Hauled

Other
Wastewater

Backwash

pH Adjust

Polishing
Filter
(Multimedia)

Discharge

Settling
(With Skimmer)

Sludge

Filtrate

Vacuum
Filter

Sludge Hauled

FIGURE X-14

MAGNESIUM SUBCATEGORY
BAT OPTION 1 TREATMENT

FIGURE X-15

MAGNESIUM SUBCATEGORY
BAT OPTION 2 TREATMENT

FIGURE X-16

MAGNESIUM SUBCATEGORY
BAT OPTION 3 TREATMENT

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Backwash

```
All Wastewater After
In-Process Water      →   [pH Adjustment]  →  [Sulfide          →  [Filtration]  →  Discharge
Reduction                                      Precipitation
                                               And
                                               Sedimentation]
```

Filtrate

Sludge

[Vacuum Filter] → **Sludge Hauled**

Additional In-Process Technology: Countercurrent rinse amalgamated zinc powder
Recirculate amalgamation area floor wash water
Countercurrent rinse after zinc anode formation
Countercurrent rinse of electrodeposited silver powder
Countercurrent rinse after silver oxide electrode formation
Reduce flow and countercurrent rinse silver peroxide
Rinse flow controls for impregnated nickel cathode rinsing
Countercurrent rinse or rinse recycle for cell washing
Countercurrent rinse after etching silver grids
Dry cleanup of plant floor; or wash water reuse

FIGURE X-17

ZINC SUBCATEGORY
BAT OPTION 1 TREAMENT

Backwash

All Wastewater After → pH Adjustment → Sulfide Precipitation And Sedimentation → Membrane Filtration → Discharge
In-Process Water
Reduction

Sludge

Filtrate → Vacuum Filter → Sludge Hauled
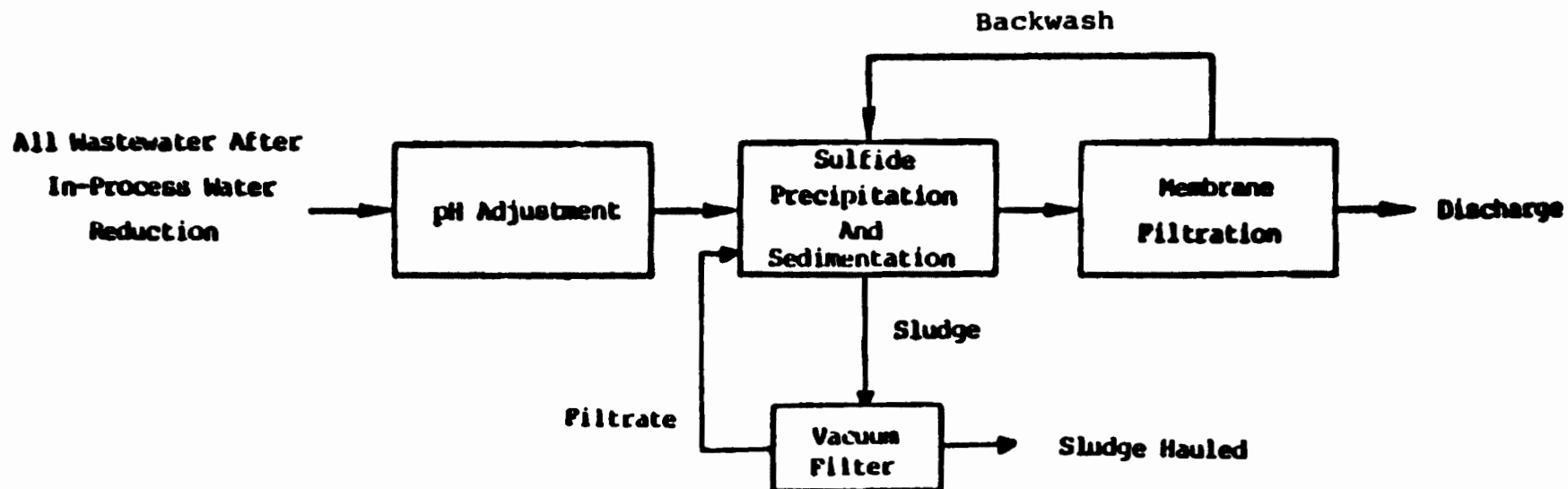
Additional In-Process Technology: Eliminate water use from gelled amalgam
Eliminate use of chromates in cell washing

FIGURE X-18

ZINC SUBCATEGORY
BAT OPTION 2 TREATMENT

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Recycle To Process

All Wastewater
After In-Process
Water Reduction

pH Adjustment → Filtration → Reverse Osmosis

Permeate

Brine

pH Adjustment

Backwash

Sludge Hauled

Sulfide Precipitation And Sedimentation → Filtration → Discharge

Filtrate

Sludge

Vacuum Filter → Sludge Hauled
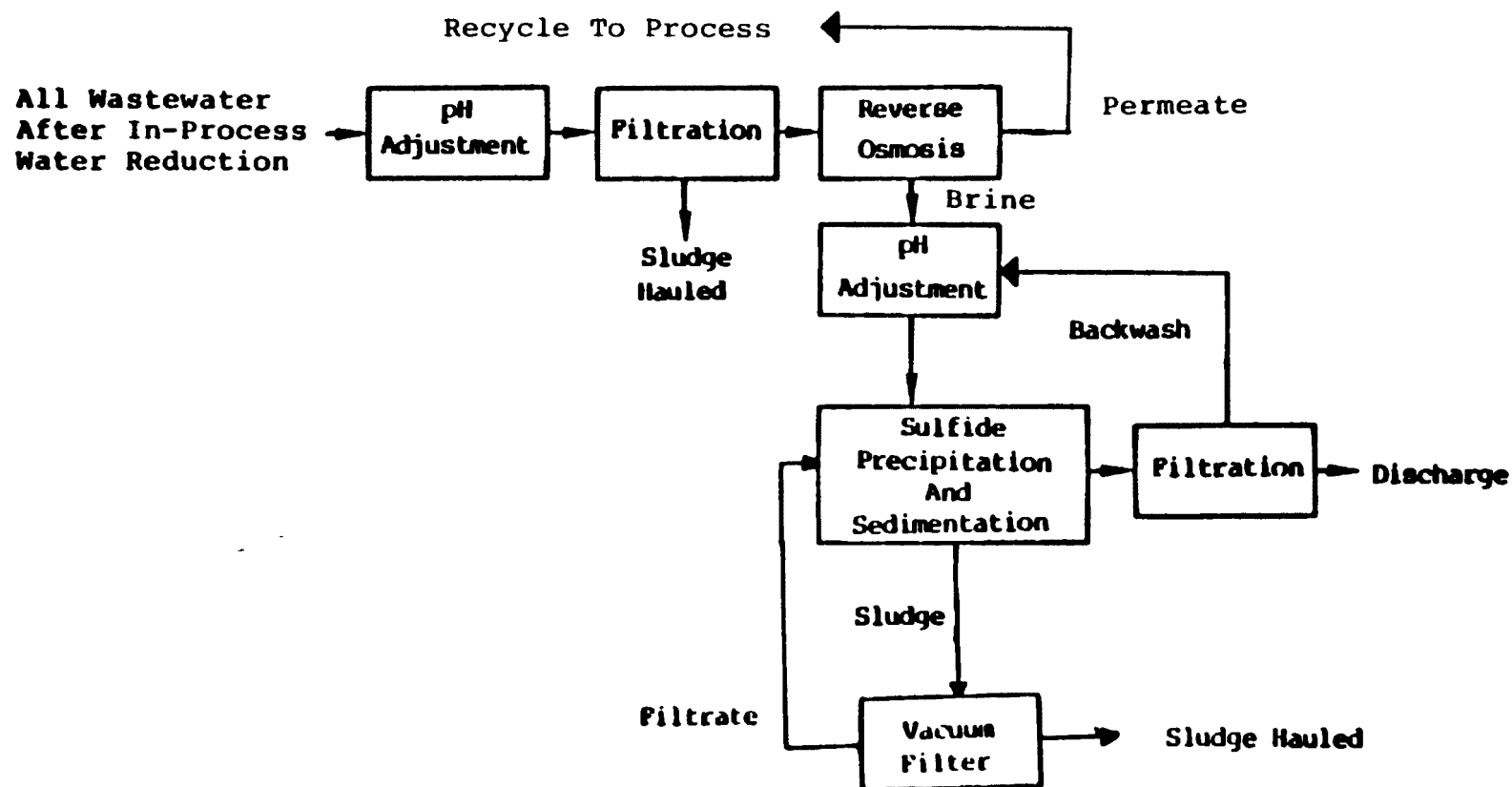
Additional In-Process Technology: Amalgamation by dry processes
Form nickel cathodes in cells

FIGURE X-19

ZINC SUBCATEGORY
BAT OPTION 3 TREATMENT

SECTION XI
NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

This section describes the best available demonstrated technology (BDT), processes, operating methods or other alternatives applicable to the control of wastewater pollutant discharges from new sources in the battery manufacturing category. Several options are presented for consideration as BDT for each subcategory, and costs for each are addressed in Section VIII of this document. Section VIII provides information concerning environmental benefits for each of the component technologies considered in these options. In general, options presented for consideration as BDT are identical to those presented for BAT in section X.

TECHNICAL APPROACH TO BDT

As a general approach for the category three options were developed for consideration as BDT for each subcategory. Each option generally includes both in-process and end-of-pipe technologies. For one subcategory, BDT is zero discharge because BPT is zero discharge of process wastewater pollutants and for another subcategory, one BDT option is zero discharge because one BAT option achieves zero discharge. Two BDT options are presented which achieve zero discharge of process wastewater pollutants from all process elements. Other options provide reduced pollutant discharge by reducing both the volume of process wastewater and the concentrations of pollutants and may include the elimination of wastewater discharge from specific process elements.

In-process technologies included in BDT options are observed in present practice within the battery manufacturing category. The emphasis in most options is on control of water use and discharge and on in-process control contributing to the efficient use of process water. These include: wastewater segregation, counter-current rinse, wastewater recycle and reuse, and flow rate controls in addition to process modifications specific to each subcategory. These control techniques have been described in Section VII, and in their specific application to each subcategory, in Section X.

End-of-pipe treatment is provided to remove toxic metals by chemical precipitation and suspended solids (including metal precipitates) by sedimentation and filtration. Different BDT options for each subcategory include different chemical precipitation or solids removal techniques. For several subcategories one BDT option provides for the use of reverse osmosis technology to significantly reduce the volume

of process wastewater which is treated for metals and TSS removal and discharged.

IDENTIFICATION OF BDT

End-of-pipe treatment included in each option considered for BDT is identical to that presented for BAT as discussed in Section X.

Cadmium Subcategory

Four options are presented for the cadmium subcategory. BDT Options 1, 2, and 3 include the same in-process and end-of-pipe technology as BAT Options 1, 2, and 3 plus the addition of multi-stage counter-current rinse tanks for the production of electrodeposited cadmium anodes. BDT Option 4 is the same as BAT Option 4. Figure X-1, 2, 3, and 4 (Pages 766 - 769) illustrate the end-of-pipe treatment for BDT Options 1, 2, 3, and 4, respectively.

Calcium Subcategory

Two options are presented for the calcium subcategory. BDT Options 1 and 2 are the same as BAT Options 1 and 2 and are illustrated in Figure X-5 and 6 (Pages 770 and 771), respectively.

Lead Subcategory

Four options are presented for the lead subcategory. BDT Options 1, 2, and 3 correspond to BAT Options 2, 3, and 4, respectively, and are illustrated by Figures X-8, 9, and 10 (Pages 773 - 775), respectively. BDT Option 4 achieves zero discharge of process wastewater pollutants by adding a second reverse osmosis unit on the effluent from BDT Option 3 and recycling permeate to the process and the brine to treatment. BDT Option 4 is illustrated in Figure XI-1 (Page 788).

Leclanche Subcategory

BDT for the Leclanche subcategory is the same as the BAT, which, in turn, is the same as BPT - zero discharge.

Lithium Subcategory

Three options are presented for the lithium subcategory. BDT Options 1, 2, and 3 are the same as BAT Options 1, 2, and 3, respectively, and are illustrated in Figures X-11, 12, and 13 (Pages 776 - 778), respectively.

Magnesium Subcategory

Three options are presented for the magnesium subcategory. BDT Options 1, 2, and 3 are the same as BAT Options 1, 2, and 3, respectively, and are illustrated in Figures X-14, 15, and 16 (Pages 779 -781), respectively.

Zinc Subcategory

Four options are presented for the zinc subcategory. BDT Options 1, 2, and 3 are the same as BAT Options 1, 2, and 3, respectively, and are illustrated by Figures X-17, 18, and 19 (Pages 782 - 784), respectively. BDT Option 4 achieves zero discharge of process wastewater pollutants by adding a second reverse osmosis unit on the effluent from BDT Option 3 and recycling permeate to the process and the brine to treatment. BDT Option 4 is illustrated in Figure XI-2 (Page 789).
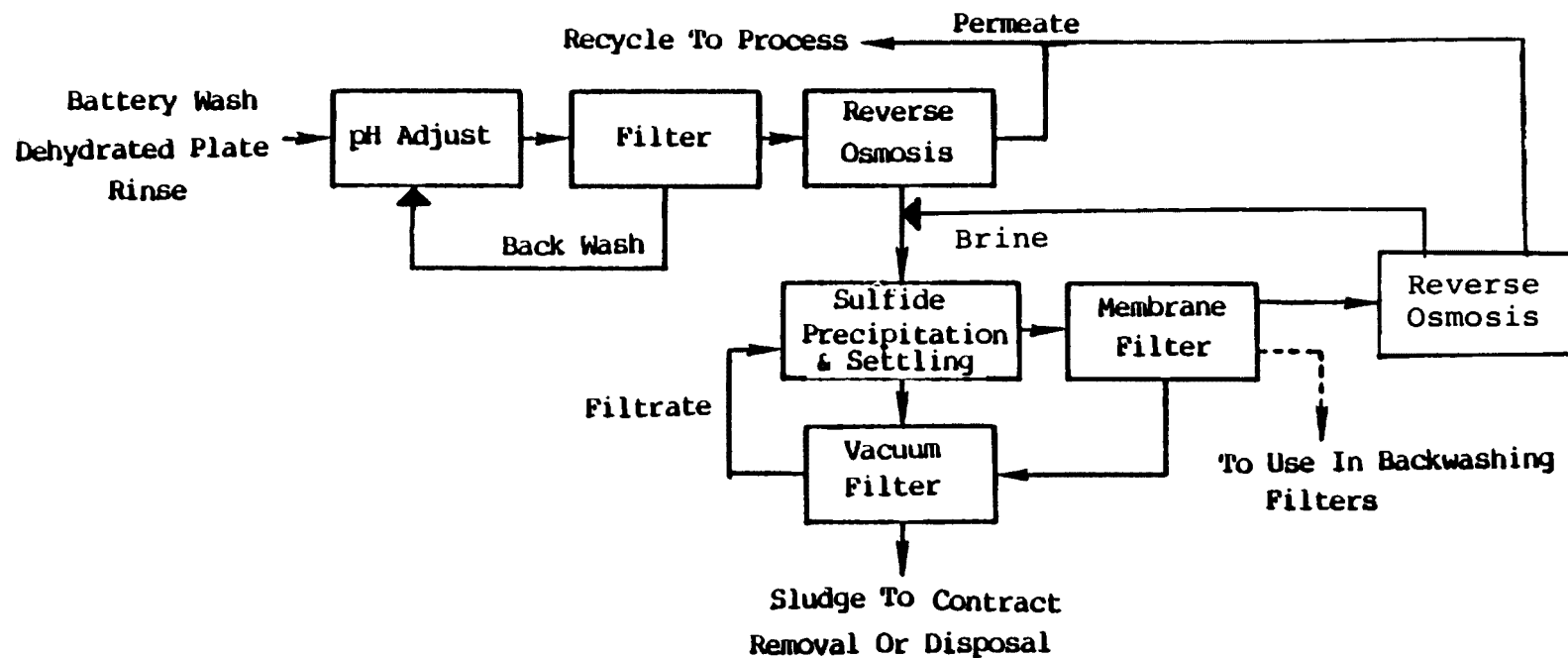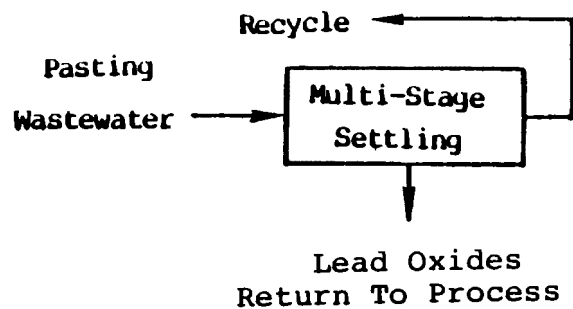
FIGURE XI-1

LEAD SUBCATEGORY
NSPS TREATMENT
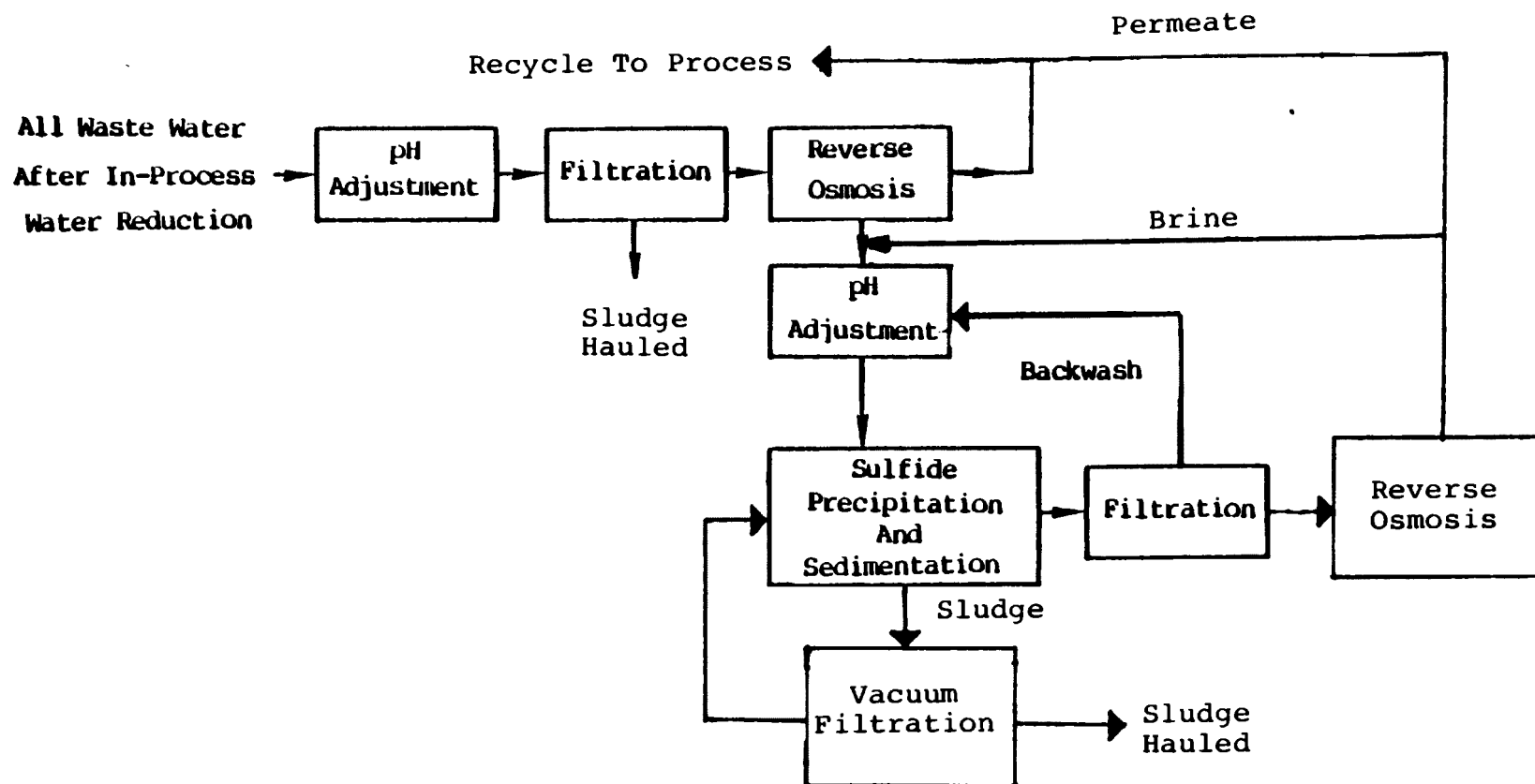
FIGURE XI-2

ZINC SUBCATEGORY
NSPS TREATMENT

SECTION XII
PRETREATMENT

Section 307(b) of the Act requires EPA to promulgate pretreatment standards for existing sources (PSES), which must be achieved within three years of promulgation. PSES are designed to prevent the discharge of pollutants which pass through, interfere with, or are otherwise incompatible with the operation of POTW's.

The Clean Water Act of 1977 adds a new dimension by requiring pretreatment for pollutants, such as heavy metals, that limit POTW sludge management alternatives, including the beneficial use of sludges on agricultural lands. The legislative history of the 1977 Act indicates that pretreatment standards are to be technology-based, analagous to the best available technology for removal of toxic pollutants.

Section 307(c) of the Act requires EPA to promulgate pretreatment standards for new sources (PSNS) at the same time that it promulgates NSPS. New indirect dischargers, like new direct dischargers, have the opportunity to incorporate the best available demonstrated technologies including process changes, in-plant controls, and end-of-pipe treatment technologies, and to use plant site selection to ensure adequate treatment system installation.

This section describes the control technology for pretreatment of process wastewaters from existing sources and new sources. The concentrations and mass discharge limitations of regulated pollutants for existing and new sources, based on the described control technology, are indicted by the data presented in Sections V and VII.

Most POTW consist of primary or secondary treatment systems which are designed to treat domestic wastes. Many of the pollutants contained in battery manufacturing wastes are not biodegradable and are therefore ineffectively treated by such systems. Furthermore, these wastes have been known to interfere with the normal operations of these systesm. Problems associated with the uncontrolled release of pollutant parameters identified in battery process wastewaters to POTW were discussed in Section VI. The discussion covered pass-through, interference, and sludge utilizability.

TECHNICAL APPROACH TO PRETREATMENT

As a general approach for the category, three options were developed for consideration as the basis for PSES and three for PSNS. These options generally provide for the removal of metals by chemical precipitation and of suspended solids by sedimentation or filtration. In addition, they generally provide for the reduction or control of

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wastewater discharge volume through the application of water use controls and a variety of in-process control techniques. The goal of pretreatment is to control pollutants which will pass through a POTW, interfere with its operation, or interfere with the use or disposal of POTW sludge. Because battery manufacturing wastewater streams characteristically contain toxic heavy metals which are incompatible with POTW, pretreatment requirements for these streams do not differ significantly from treatment requirements for direct discharge. Consequently the options presented for PSES and PSNS are identical to treatment and control options presented for BAT and NSPS, respectively. These options generally combine both in-plant technology and wastewater treatment to reduce the mass of pollutants (especially heavy metals) which will pass through the POTW or contaminate the POTW sludge.

Factors considered in selecting the specific technology options presented have been discussed in Sections IX, X and XI. The same considerations apply to pretreatment prior to introduction of the wastewater into a POTW.

IDENTIFICATION OF PRETREATMENT OPTIONS

Option one for pretreatment standards for existing sources (PSES) is identical to BPT for all subcategories as described in Section IX. Options two and three for each subcategory are identical to BAT options one and two respectively. End-of-pipe treatment systems for each of these options are depicted in Sections IX or X as appropriate. Pretreatment options for new sources are identical to BDT options for each subcategory as described in Section XI.

Effluent performance achieved by these pretreatment options will the same as that provided by the respective BPT, BAT and BDT options and is indicated by the flow rate information provided in Section V and the technology performance data shown in Section VII.

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SECTION XIII
BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 amendments added section 301(b)(4)(E) to the Act, establishing "best conventional pollutant control technology" (BCT) for discharges of conventional pollutants from existing industrial point sources. Conventional pollutants are those defined in section 304(b)(4) - BOD, TSS, fecal coliform and pH - and any additional pollutants defined by the Administrator as "conventional." On July 30, 1979, EPA designated oil and grease as a conventional pollutant (44 Fed. Reg. 44501).

BCT is not an additional limitation, but replaces BAT for the control of conventional pollutants. BCT requires that limitations for conventional pollutants be assessed in light of a new "cost-reasonableness" test, which involves a comparison of the cost and level of reduction of conventional pollutants from the discharge of POTW's to the cost and level of reduction or such pollutants from a class or category of industrial sources. As part of its review of BAT for certain industries, EPA proposed methodology for this cost test. (See 44 Fed. Reg. 50732, August 29, 1979). This method is now used for the primary industries covered by the Consent Agreement.

EPA is proposing that the conventional "indicator" pollutants, which are used as "indicators" of control for toxic pollutants, be treated as toxic pollutants. In this way, effluent limitations will be established for the conventional indicator pollutants at BAT levels, and the limitations will not have to pass the BCT cost test. When a permittee, in a specific case, can show that the waste stream does not contain any of the toxic pollutants that a conventional toxic "indicator" was designed to remove, then the BAT limitation on that conventional pollutant will no longer be treated as a limitation on a toxic pollutant. The technology identified as BAT control of toxic pollutants also affords removal of conventional pollutants to BAT levels.

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SECTION XIV
ACKNOWLEDGEMENTS

SECTION XV
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GLOSSARY

Active Material - Electrode material that reacts chemically to produce ele trical energy when a cell discharges. Also, such material in its original composition, as applied to make an electrode.

Air Scrubling - A method of removing air impurities such as dust or fume by contact with sprayed water or an aqueous chemical solution.

Alkalinity - (1) The extent to which an aqueous solution contains more hydroxyl ions than hydrogen ions. (2) The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates and phosphates.

Amalgamation - (1) Alloying of a zinc anode with mercury to prevert internal corrosion and resultant gassing in a cell. (2) Treatment of waste water by passing it through a bed of metal particles to alloy and thereby remove mercury from the water.

Anode - The electrode by which electrons leave a cell. The negative electrode in a cell during discharge.

Attrition Mill - A ball mill in which pig lead is ground to a powder and oxidized to make the active material in lead acid batteries.

Backwashing - The process of cleaning a filter or ion exchange column by a reverse flow of water.

Baffles - Deflector vanes, guides, grids, gratings, or similar devices constructed or placed in flowing water or sewage to (1) effect a more uniform distribution of velocities; (2) divert, guide, or agitate the liquids.

Bag House - The large chamber for holding bag filters used to filter gas streams from a furnace such as in manufacture of lead oxide.

Ball Mill - A reactor in which pig lead is ground to a powder and oxidized to make the active material for lead acid batteries.

Barton Pot - Another device for making leady oxide.

Batch Treatment - A waste treatment method where waste water is collected over a period of time and then treated prior to discharge, often in the same vessel in which it is collected.

Battery - A device that transforms chemical energy into electrical energy. This term also applies to two or more cells connect in series, parallel or a combination of both.

Bobbin - An assembly of the positive current collector and cathode material, usually molded into a cylinder.

Buffer - Any of certain combinations of chemicals used to stabilize the pH values or alkalinities of solutions.

Button Cell - A tiny, circular battery, any of several types, made for a watch or other microelectronic application.

Burn - Connection of terminals or connectors to a lead acid battery by welding.

Can - The outer case of a cylindrical cell.

Carcinogen - A substance that causes cancer.

Casting - The process by which grids for lead acid batteries are made by shaping molten lead in molds.

Cathode - The electrode by which electrons enter a cell. The positive electrode in a cell during discharge.

Cathodic Polarization - Electrical connection of a nickel electrode plaque to promote deposition of active nickel material.

Caustic - (1) An alkaline battery electrolyte, sodium or potassium hydroxide. (2) Sodium hydroxide, used to precipitate heavy metals from waste water.

Cell - The basic building block of a battery. It is an electrochemical device consisting of an anode and a cathode in a common electrolyte kept apart with a separator. This assembly may be in its own container or be an individual compartment of a battery.

Central Treatment Facility - Treatment plant which co-treats process waste waters from more than one manufacturing operation or co-treats process waste waters with noncontact cooling water, or with nonprocess waste waters (e.g., utility blowdown, miscellaneous runoff, etc).

Centrifugation - Use of a centrifuge to remove water in the manufacture of active material or in the treatment of waste water sludge.

Charge - The conversion of electrical energy into chemical energy within a cell-battery. This restoration of active electrode materials is done by forcing a current through the cell-battery in the opposite direction to that during discharge. See "formation."

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 oxidization of organics in a liquid.

Chemical Precipitation - The use of an alkaline chemical to remove dissolved heavy metals from waste water.

Chemical Treatment - Treating contaminated water by chemical means.

Clarifier - A unit which provides settling and removal of solids from waste water.

CMC - Sodium carboxymethyl cellulose; an organic liquid used as a binder in electrode formulations.

Colloids - A finely divided dispersion of one material called the "dispersed phase" (solid) in another material which is called the "dispersion medium" (liquid).

Compatible Pollutant - An industrial pollutant that is successfully treated by a secondary municipal treatment system.

Composite Waste Water Sample - A combination of individual samples of water or waste water taken at selected intervals and mixed in proportion to flow or time to minimize the effect of the variability of an individual grab sample.

Concentration, Hydrogen Ion - The weight of hydrogen ions in grams per liter of solution. Commonly expressed as the pH value that represents the logarithm of the reciprocal of the hydrogen ion concentration.

Contamination - A general term signifying the introduction into water of microorganisms, chemicals, wastes or sewage which renders the water unfit for its intended use.

Contractor Removal - The disposal of oils, spent solutions, waste waters, or sludge by means of an approved scavenger service.

Cooling Tower - A device used to cool noncontact water used in the manufacturing processes before returning the water for reuse.

Current Collector - The grid portion of the electrode which conducts the current to the terminal.

Cyclone Separator - A funnel-shaped device for removing particles from air or other fluids by centrifugal means. ·

Decantation - A method for mechanical dewatering of a wet solid by pouring off the liquid without disturbing the underlying sediment or precipitate.

Demineralization - The removal from water of mineral contaminants usually present in ionized form. The methods used include ion-exchange techniques, flash distillation or reverse osmosis.

Depolarizer - A term often used to denote the cathode active material.

Dewatering - Any process whereby water is removed from sludge.

Discharge - Release of electric power from a battery.

Discharge of Pollutant(s) - The addition of any pollutant to navigable waters from any point source.

Dissolved Oxygen (DO) - The oxygen dissolved in sewage, water, or other liquid, usually expressed in milligrams per liter.

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 waste water treatment, the Standard Methods tests are used.

Dry Charge Process - A process for the manufacture of lead acid storage batteries in which the plates are charged by electrolysis in sulfuric acid, rinsed, and dried prior to shipment of the battery. Charging of the plates usually occurs in separate containers before assembly of the battery but may be accomplished in the battery case. Batteries produced by the dry-charge process are shipped without acid electrolyte.

Drying Beds - Areas for dewatering of sludge by evaporation and seepage.

Effluent - Industrial waste water discharged to a sanitary sewer, stream, or other disposal point outside the plant property.

Electrode - The positive (cathode) or negative (anode) element in a cell or battery, that enables it to provide electric power.

Electrodeposition - Deposition of an active material from solution onto an electrode grid or plaque by electrochemical means.

Electroforming - See (1) electrodeposition, and (2) formation.

Electroimpregnation - See cathodic polarization.

Electrolyte - The liquid or material that permits conduction of ions between cell electrodes.

Electrolytic Precipitation - Generally refers to making powdered active material by electrodeposition and physical removal; e.g., silver powder from silver bars

Electroplating - (1) Electrodeposition of a metal or alloy from a suitable electrolyte solution; the article to be plated is connected as the cathode in the electrolyte solution; direct current is introduced through the anode which consists of the metal to be deposited. (2) The Electroplating Point Source Category.

Element - A combination of negative and positive plates and separators to make a cell in a lead-acid storage battery.

End-of-Pipe Treatment - The reduction and/or removal of pollutants by treatment just prior to actual discharge to a point outside an industrial plant.

Equalization - The process whereby waste streams from different sources varying in pH, chemical constituents, and flow rates are collected in a common container. The effluent stream from this equalization tank will have a fairly constant flow and pH level, and will contain a homogeneous chemical mixture. This tank will help to prevent an unnecessary shock to the waste treatment system.

Evaporation Ponds - A pond, usually lined, for disposal of waste water by evaporation; effective only in areas of low rainfall.

Filter, Rapid Sand - A filter for the purification of water where water which has been previously treated, usually by coagulation and sedimentation, is passed through a filtering medium consisting of a layer of sand or prepared anthracite coal or other suitable material, usually from 24 to 30 inches thick and resting on a supporting bed of gravel or a porous medium such as carborundum. The filtrate is removed by a drain system. The filter is cleaned periodically by reversing the flow of the water upward through the filtering medium. Sometimes supplemented by mechanical or air agitation during backwashing to remove impurities that are lodged in the sand.

Filter, Trickling - A filter consisting of an artificial bed of coarse material, such as broken stone, clinkers, slats, or plastic media over which waste water is distributed and applied in drops, films, or spray, from troughs, drippers, moving distributors or fixed nozzles and through which it trickles to the under-drain, oxidizing organic materials by means of microorganisms attached to the filter media.

Filter, Vacuum - A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth revolving with a partial submergence in liquid. A vacuum is maintained under the cloth for the larger part of a revolution to extract

Filtrate - Liquid after passing through a filter.

Filtration - Removal of solid particles from liquid or particles from air or gas stream through a permeable membrane or deep bed.

    Types: Gravity, Pressure, microstraining, ultrafiltration, Reverse Osmosis (hyperfiltration).

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 floc in water or sewage.

Flocculation - In water and waste water treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by addition of chemicals and gentle stirring by either mechanical or hydraulic means.

Flock - Natural or synthetic fiber added to lead-acid battery paste as a stiffening agent.

Flow Proportioned Sample - See "Composite Waste Water Sample".

Formation - An electrochemical process which converts the battery electrode material into the desired chemical condition. For example, in a silver-zinc battery the silver applied to the cathode is converted to silver oxide and the zinc oxide applied to the anode is converted to elemental zinc. "Formation" is generally used interchangably with "charging", although it may involve a repeated charge-discharge cycle.

Gelled Electrolyte - Electrolyte which may or may not be mixed with electrode material, that has been gelled with a chemical agent to immobilize it.

GPD - Gallons per day.

Grab Sample - A single sample of waste water taken at neither set time nor flow.

Grease - In waste water, a group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oil, and certain other nonfatty materials.

Grease Skimmer - A device for removing grease or scum from the surface of waste water in a tank.

Grid - The support for the active materials and a means to conduc. current from the active materials to the cell terminals; usually a metal screen, expanded metal mesh, or a perforated metal plate.

Hardness - A characteristic of water, imparted by salts of calciu, magnesium, and iron such as bicarbonates, carbonates, sulfat s, chlorides, and nitrates that cause curdling of soap, deposit on of scale in boilers, damage in some industrial processes, and sometimes objectionable taste. It nay 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.

Heavy Metals - A general name given to the ions of metallic elements such as copper, zinc, chromium, and nickel. They are normally removed from waste water by forming an insoluble precipitate (usually a metallic hydroxide).

Holding Tank - A tank for accumulating waste water prior to treatment.

Hydrazine Treatment - Application of a reducing agent to form a conductive metal film on a silver oxide cathode.

Hydroquinone - A developing agent used to form a conductive metal film on a silver oxide cathode.

Impregnation - Methode of making an electrode by precipitating active material on a sintered nickel plaque.

In-Process Control Technology - The regulation and conservation of chemicals and rinse water throughout the operations as opposed to end-of-pipe treatment.

Industrial Wastes - The liquid wastes from industrial processes as distinct from domestic or sanitary wastes.

Influent - Water or other liquid, either raw or partly treated, flowing into a treatment step or plant.

Ion Exchange - Waste water treatment by contact with a resin that exchanges harmless ions (e.g. sodium) for toxic inorganic ions (e.g. mercury), which the resin adsorbs.

Jacket - The outer cover of a dry cell battery, usually a paper-plastic laminate.

Kjeldahl Nitrogen - A method of determining the ammonia and organically bound nitrogen in the -3 valence state but does not determine nitrite, azides, nitro, nitroso, oximes or nitrate nitrog...

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Lagoon - A man-made pond or lake for holding waste water for the removal of suspended solids. Lagoons are also used as retention ponds after chemical clarificaton to polish the effluent and to safeguard against upsets in the clarifier; for stabilization of organic matter by biological oxidation; for storage or sludge; and for cooling of water.

Landfill - The disposal of inert, insoluble waste solids by dumping at an approved site and covering with earth.

Leaching - Dissolving out by the action of a percolating liquid, such as water, seeping through a landfill, which potentially contaminates ground water.

Lime - Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite) which is composed almost wholly of calcium carbonates or a mixture of calcium and magnesium carbonates.

Limiting Orifice - A device that limits flow by constriction to a relatively small area. A constant flow can be obtained over a wide range of upstream pressures.

Make-Up Water - Net amount of water used by any process/process step, not including recycled water.

Mass - The active material used in a pocket plate cell, for example "nickel mass."

Milligrams Per Liter (mg/l) - This is a weight per volume concentration designation used in water and waste water analysis.

Mixed Media Filtration - A depth filter which uses two or more filter materials of differing specific gravities selected so as to produce a filter uniformly graded from coarse to fine.

National Pollutant Discharge Elimination System (NPDES) - The federal mechanism for regulating point source discharge by means of permits.

Neutralization - Chemical addition of either acid or base to a solution such that the pH is adjusted to approximately 7.

Non-Contact Cooling Water - Water used for cooling which does not come into direct contact with any raw material, intermediate product, waste product or finished product.

Outfall - The point or location where waste water discharges from a sewer, drain, or conduit.

Oxidation - 1. Chemical addition of oxygen atom(s) to a chemical compound; 2. In general, any chemical reaction in which an element or ion is raised to a more positive valence state; 3. The process at a battery anode during discharge.

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 cannot be measured unless the sill is submerged more than about 67 percent.

Paste - Powdered active material mixed with a liquid to form a paste for ease of application to a grid to make an electrode.

Pasting Machine - An automatic machine for applying lead oxide paste in the manufacture of lead-acid batteries.

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. At pH lower than 7, a solution is acidic. At pH higher than 7, a solution is alkaline.

pH Adjustment - A means of treating waste water by chemical addition; usually the addition of lime to precipitate heavy metal pollutants.

Plaque - A porous body of sintered metal on a metal grid used as a current collector and holder of electrode active materials, especially for nickel-cadmium batteries.

Plate - A positive or negative electrode used in a battery, generally consisting of active material deposited on or in a current-collecting support.

Pocket Plate - A type of battery construction where the electrode is a perforated metal envelope containing the active material.

Point Source - Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Pollutant Parameters - Those constitutents of waste water determined to be detrimental and, therefore, requiring control.

Polyelectrolytes - Materials used as a coagulant or a coagulant aid in water and waste water treatment. They are synthetic or natural polymers containing ionic constituents. They may be cationic, anionic, or nonionic.

Post - A battery terminal, especially on a lead-acid battery.

Precipitation - Process of separation of a dissolved substance from a solution or suspension by chemical or physical change, usually as an insoluble solid.

Pressed Powder - A method of making an electrode by pressing powdered active material into a metal grid.

Pressure Filtration - The process of solid-liquid phase separation effected by forcing the more permeable liquid phase through a mesh which is impenetrable to the solid phase.

Pretreatment - Any waste water treatment process used to reduce pollution load partially before the waste water is introduced into a main sewer system or delivered to a municipal treatment plant.

Primary Battery - A battery which must usually be replaced after one discharge; i.e., the battery cannot be recharged.

Primary Settling - The first settling unit for the removal of settleable solids through which waste water is passed in a treatment works.

Primary Treatment - A process to remove substantially all floating and settleable solids in waste water and partially reduce the concentration of suspended solids.

Priority Pollutant - The 129 specific pollutants established by the EPA from the 65 pollutants and classes of pollutants as outlined in the consent decree of June 8, 1976.

Process Waste Water - Any water which, during manufacturing or processing, comes into direct contact with or results from the production or use of any raw materials, intermediate product, finished product, by-product, or waste product.

Process Water - Water prior to its direct contact use in a process or operation. This water may be any combination of raw water, service water, or either process waste water or treatment facility effluent to be recycled or reused.

Raw Water - Plant intake water prior to any treatment or use.

Recycled Water - Process waste water or treatment facility effluent which is recirculated to the same process.

Reduction - 1. A chemical process in which the positive valence of a species is decreased.
2. Waste water treatment to (a) convert hexavalent chromium to the trivalent form, or (b) reduce and precipitate mercury ions.

Reserve Cell - A class of cells which are designated as "reserve", because they are supplied to the user in a non-activated state. Typical of this class of cell is the carbon-zinc air reserve cell, which is produced with all the components in a dry or non-activated state, and is activated with water when it is ready to be used.

Retention Time - The time allowed for solids to collect in a settling tank. Theoretically retention time is equal to the volume of the tank divided by the flow rate. The actual retention time is determined by the purpose of the tank. Also the design residence time in a tank or reaction vessel which allows a chemical reaction to go to completion, such as the reduction of hexavalent chromium or the destruction of cyanide.

Reused Water - Process waste water or treatment facility effluent which is further used in a different manufacturing process.

Reverse Osmosis (Hyperfiltration) - A treatment or recovery process in which polluted water is put under a pressure greater than the osmotic pressure to drive water across the membrane while leaving behind the dissolved salts as a concentrate.

Reversible Reaction - A chemical reaction capable of proceeding in either direction depending upon the conditions.

Rinse - Removal of foreign materials from the surface of an object by flow or impingement of a liquid (usually water) on the surface. In the battery industry, "rinse" may be used interchangeably with "wash."

Ruben - Developer of the Hg-Zn battery; also refers to the Hg-Zn battery.

Sand Filtration - A process of filtering waste water through sand. The waste water is trickled over the bed of sand, which retains suspended solids. The clean water flows out through drains in the bottom of the bed. The solids accumulating at the surface must be removed from the bed periodically.

Sanitary Sewer - A sewer that carries liquid and water carried wastes to a municipal treatment plant.

Sanitary Water - Waste water from toilets, sinks, and showers.

Scrubber - General term used in reference to an air pollution control device that uses a water spray.

Sealed Cell - A battery cell which can operate in a sealed condition during both charge and discharge.

Secondary Cell - An electrochemical cell or battery system that can be recharged; a storage battery.

Secondary Waste Water Treatment - The treatment of waste water by biological methods after primary treatment by sedimentation.

Sedimentation - The process of subsidence and deposition of suspended matter carried by water, waste water, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling.

Separator - A porous material, in a battery system, used to keep plates of opposite polarity separated, yet allowing conduction of ions through the electrolyte.

Service Water - Raw water which has been treated preparatory to its use in a process or operation; i.e., make-up water.

Settling Ponds - A large shallow body of water into which industrial waste waters are discharged. Suspended solids settle from the waste waters due to the large retention time of water in the pond.

Settleable Solids - (1) That matter in waste water which will not stay in suspension during a preselected settling period, such as one hour, but settles to the bottom. (2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone is one hour.

Sewer - A pipe or conduit, generally closed, but normally not flowing full or carrying sewage and other waste liquids.

SIC - Standard Industrial Classification - Defines industries in accordance with the composition and structure of the economy and covers the entire field of economic activity.

Silver Etch - Application of nitric acid to silver foil to prepare it as a support for active material.

Sinter - Heating a metal powder such as nickel to a temperature below its melting point whch causes it to agglomerate and adhere to the supporting grid.

Sintered-plate electrode - The electrode formed by sintering metallic powders to form a porous structure, which serves as a current collector, and on which the active electrode material is deposited.

Skimming Tank - A tank so designed that floating matter will rise and remain on the surface of the waste water until removed, while the liquid discharges continuously under certain walls or scum boards.

Sludge - A suspension, slurry, or solid matter produced in a waste treatment process.

Sludge Conditioning - A process employed by prepare sludge for final disposal. Can be thickening, digesting, heat treatment etc.

Sludge Disposal - The final disposal of solid wastes.

Sludge Thickening - The increase in solids concentration of sludge in a sedimentation or digestion tank or thickener.

Solvent - A liquid capable of dissolving or dispersing one or more other substances.

Spills - A chemical or material spill is an unintentional discharge of more than 10 percent of the 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.

Sponge - A high..y porous metal powder.

Stabilization Lagoon - A shallow pond for storage of waste water before discharge. Such lagoons may serve only to detain and equalize waste water composition before regulated discharge to a stream, but often they are used for bioligical oxidatio i.

Stabilization Pond - A type of oxidation pond in which biological oxidation of organic matter is effected by natural or artifi- cially accelerated transfer of oxygen to the water from air.

Storage Battery - A battery that can store chemical energy with the potential to change to electricity. This conversion of chemical energy to electricity can be reversed thus allowing the battery to be recharged.

Strap - A metal conductor connecting individual cells to form a battery.

Sump - A pit or tank which receives and temporarily stores drainage or waste water at the lowest point of a circulating or drainage system.

Suspended Solids - (1) Solids that are in suspension in water, waste water, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from waste water in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Waste Water" and referred to as non-filterable residue.

Surface Waters - Any visible stream or body of water.

Terminal - The part of a battery to which an external circuit is connected.

Thickener - A device wherein the solids contents of slurries or suspensions are increased by gravity settling and mechanical separation of the phases, or by flotation and mechanical separation of the phases.

Total Cyanide - The total content of cyanide including simple and/or complex ions. In analytical terminology, total cyanide is the sum of cyanide amenable to chlorination and that which is not according to standard analytical methods.

Total Solids - The total amount of solids in a waste water in both solution and suspension.

Toxicity - Referring to the ability of a substance to cause injury to an organism through chemical acitivty.

Treatment Efficiency - Usually refers to the percentage reduction of a specific pollutant or group of pollutants by a specific waste water treatment step or treatment plant.

Treatment Facility Effluent - Treated process waste water.

Turbidity - (1) A condition in water or waste water 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.

Vacuum Filtration - See **Filter, Vacuum**.

Vented Cell - A type of battery cell which has a vent that allows the escape of gas and the addition of water.

Wash - Application of water, an aqueous solution, or an organic solvent to a battery part to remove contaminating substances.

Water Balance - An accounting of all water entering and leaving a unit process or operation in either a liquid or vapor form or via raw material, intermediate product, finished product, by-product, waste product, or via process leaks, so that the difference in flow between all entering and leaving streams is zero.

Weir - A device that has a crest and some 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.

Wet Charge Process - Fabrication technique for lead-acid storage batteries whereby elements are formed inside the assembled battery case by electrical activation in sulfuric acid. The battery is shipped with sulfuric acid electrolyte inside the battery casing.

Wet Shelf Life - The period of time that a secondary battery can stand in the charged condition before total degradation.

Wet Scrubber - A unit in which dust and fumes are removed from an air or gas stream to a liquid. Gas-liquid contact is provided by jets, sprays, bubble chambers, etc.

METRIC TABLE

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
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier