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Final

Point Source Category
Volume II

Subcategory:
Lead

VOLUME II

DEVELOPMENT DOCUMENT
for
EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS
for the
BATTERY MANUFACTURING
POINT SOURCE CATEGORY

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This volume is dedicated to John Allen von Hemert who worked diligently as a member of the EPA Battery Project team, and who suddenly passed away January 29, 1984.

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SECTION I

SUMMARY AND CONCLUSIONS

Background

Pursuant to Sections 301, 304, 306, 307, 308, and 501 of the Clean Water Act, and the Settlement Agreement in Natural Resources Defense Council v. Train 8 ERC 2120 (D.D.C. 1976) modified 12 ERC 1833 (D.D.C. 1979) by orders dated October 26, 1982, August 2, 1983, and January 6, 1984, EPA collected and analyzed data for plants in the Battery Manufacturing Point Source Category. There are no existing effluent limitations or performance standards for this industry. This document and the administrative record provide the technical bases for promulgating effluent limitations for existing direct dischargers using best practicable and best available technology (BPT and BAT). Effluent standards are promulgated for existing indirect dischargers (PSES), and new sources, for both direct dischargers (NSPS) and indirect dischargers (PSNS).

Battery manufacturing encompasses the production of modular electric power sources where part or all of the fuel is contained within the unit and electric power is generated directly from a chemical reaction rather than indirectly through a heat cycle engine. There are three major components of a cell -- anode, cathode, and electrolyte -- plus mechanical and conducting parts such as case, separator, or contacts. Production includes electrode manufacture of anodes and cathodes, and associated ancillary operations necessary to produce a battery.

This volume (Volume II) of the development document specifically addresses the lead subcategory and Volume I addresses all other subcategories within the battery manufacturing point source category. Section III of both volumes provides a general discussion of all battery manufacturing.

Subcategorization

The category is subcategorized on the basis of anode material and electrolyte. This subcategorization was selected because most of the manufacturing process variations are similar within these subcategories and the approach avoids unnecessary complexity. The data base for this volume includes all information for the lead subcategory.

Within the lead subcategory manufacturing process operations (or elements) were grouped into anode manufacture, cathode manufacture, and ancillary operations associated with the production of a battery. The development of a production normalizing parameter (pnp) for each element was necessary to relate water use to various plant sizes and production variations. For the lead subcategory the total (raw material) lead use was selected as the pnp and is generally applied to all process elements.

Data.

The data base for the lead subcategory includes 186 plants which employed an estimated 18,745 people. Of the 186 plants, 12 discharge wastewater directly to surface waters, 117 discharge wastewater to publicly owned treatment works (POTW), and 57 have no discharge of process wastewater. Data collection portfolios (dcp) were sent to all known battery companies in the U.S. and data were requested for 1976. Data were returned by 96 percent of the lead battery companies. The data base includes some data for 1977, 1978, and 1982.

Water is used throughout lead battery manufacturing to clean battery components and to transport wastes. Water is used in paste mixing to make lead electrodes; water is also a major component of the sulfuric acid electrolyte which is also contained in formation baths. A total of 17 lead battery plants were visited before proposal for engineering analysis, and wastewater sampling was conducted at five of these plants. These visits enabled the Agency to characterize subcategory specific wastewater generating processes, select the pollutants for regulation, and evaluate wastewater treatment performance in this subcategory. Since proposal, 17 additional lead battery manufacturing sites were visited in order to collect additional data and to further evaluate wastewater treatment performance.

Pollutants or pollutant parameters found in significant amounts in lead battery manufacturing wastewaters include (1) toxic metals -- copper and lead; (2) nonconventional pollutants -- aluminum, iron, manganese; and (3) conventional pollutants -- oil and grease, TSS, and pH. Toxic organic pollutants generally were not found in large quantities. Because of the amount of toxic metals present, the sludges generated during wastewater treatment generally contain substantial amounts of toxic metals.

Current wastewater treatment systems in the battery manufacturing category range from no treatment to sophisticated physical chemical treatment (although frequently not properly operated) combined with water conservation practices. Of the 186 lead battery manufacturing plants in the data base, 23 percent of the plants have no treatment and do not discharge, 17 percent have no treatment and discharge, 20 percent have only pH adjust systems, 5 percent have only sedimentation or clarification devices, 29 percent have equipment for chemical precipitation and settling, 5.5 percent have equipment for chemical precipitation, settling and filtration, and 0.5 percent have other treatment systems. Even though treatment systems are in-place at many plants, wastewater treatment practices in this subcategory are uniformly inadequate. The systems in-place are generally inadequately sized, poorly maintained, or improperly operated (systems overloaded, solids not removed, pH not controlled, etc.).

Wastewater Treatment

The control and treatment technologies available for this category and considered as the basis for the promulgated regulation include both in-process and end-of-pipe treatments. In-process treatment includes a variety of water flow reduction steps and major process changes such as: cascade and countercurrent rinsing (to reduce the amount of water used to remove unwanted materials from electrodes); consumption of cleansed wastewater in product mixes; and substitution of nonwastewater-generating formation (charging) systems. End-of-pipe treatment considered includes: chemical precipitation of metals using hydroxides, carbonates, or sulfides; and removal of precipitated metals and other materials using settling or sedimentation; filtration; reverse osmosis; and combinations of these technologies. While developing the final regulation, EPA also considered the impacts of these technologies on air quality, solid waste generation, water scarcity, and energy requirements.

The effectiveness of these treatment technologies has been evaluated and established by examining their performance on battery manufacturing and other similar wastewaters. The data base for hydroxide precipitation-sedimentation (lime and settle) technology is a composite of data drawn from EPA sampling and analysis of copper and aluminum forming, battery manufacturing, porcelain enameling, and coil coating effluents. A detailed statistical analysis done on the data base showed substantial homogeneity in the treatment effectiveness data from these five categories. This supports EPA's technical judgment that these wastewaters are similar in all material respects for treatment because they contain a range of dissolved metals which can be removed by precipitation and solids removal. Electroplating data were originally used in the data set, but were excluded after further statistical analyses were performed. Following proposal, additional battery manufacturing lime and settle technology effluent data were obtained from battery plants primarily to evaluate treatment effectiveness for lead. Precipitation-sedimentation and filtration technology performance is based on the performance of full-scale commercial systems treating multi-category wastewaters which also are essentially similar to battery manufacturing wastewaters.

The treatment performance data is used to obtain maximum daily and monthly average pollutant concentrations. These concentrations (mg/l) along with the production normalized regulatory flows (l/kg of production normalizing parameter) are used to obtain the maximum daily and monthly average values (mg/kg) for effluent limitations and standards. The monthly average values are based on the average of ten consecutive sampling days. The ten day average value was selected as the minimum number of consecutive samples which need to be averaged to arrive at a stable slope on a statistically based curve relating one day and 30 day average values and it approximates the most frequent monitoring requirement of direct discharge permits.

Treatment Costs

The Agency estimated the costs of each control and treatment technology using a computer program based on standard engineering cost analysis. EPA derived unit process costs by applying plant data and characteristics (production and flow) to each treatment process (i.e., metals precipitation, sedimentation, mixed-media filtration, etc.). The program also considers what treatment equipment exists at each plant. These unit process costs were added for each plant to yield total cost at each treatment level. In cases where there is more than one plant at one site, costs were calculated separately for each plant and probably overstate the actual amount which would be spent at the site where one combined treatment system could be used for all plants. These costs were then used by the Agency to estimate the impact of implementing the various options on the industry. For each control and treatment option considered the number of potential closures, number of employees affected, and the impact on price were estimated. These results are reported in the EPA document entitled, Economic Impact Analysis of Effluent Limitations and Standards for the Battery Manufacturing Industry (EPA 440/2-84-002).

Regulation

On the basis of raw waste characteristics, in-process and end-of-pipe treatment performance and costs, and other factors, EPA identified and classified various control and treatment technologies as BPT, BAT, NSPS, PSES, and PSNS. The regulation, however, does not require the installation of any particular technology. Rather, it requires achievement of effluent limitations equivalent to those achieved by the proper operation of these or equivalent technologies.

Except for pH requirements, the effluent limitations for BPT, BAT, and NSPS are expressed as mass limitations -- a mass of pollutant per unit of production (mg/kg). They were calculated by combining three figures: (1) treated effluent concentrations determined by analyzing control technology performance data; (2) production-weighted wastewater flow for each manufacturing process element of each subcategory; and (3) any relevant process or treatment variability factor (e.g., mean versus maximum day). This basic calculation was performed for each regulated pollutant or pollutant parameter and for each wastewater-generating process element of each subcategory. Pretreatment standards -- PSES and PSNS -- are also expressed as mass limitations rather than concentration limits to ensure a reduction in the total quantity of pollutant discharges.

BPT - In general, the BPT level represents the average of the best existing performances of plants of various ages, sizes, processes or other common characteristics. Where existing performance is uniformly inadequate, BPT may be transferred from a different subcategory or category. In balancing costs in relation to effluent reduction benefits, EPA considers the volume and nature of existing discharges, the volume and nature of discharges expected after application of BPT, the general environmental effects of the pollutants, and cost and economic impact of the required pollution control level.

EPA is promulgating BPT mass limitations for existing direct dischargers based on model end-of-pipe treatment, which consists of oil skimming when required and lime precipitation and settling. The pollutant parameters selected for limitation at BPT are: copper, lead, iron, oil and grease, total suspended solids (TSS), and pH.

Twelve lead battery plants are direct dischargers. Implementation of BPT limitations will remove 115,400 kilograms (253,900 pounds) per year of toxic metals and 675,800 kilograms (1,486,800 pounds) per year of conventional and other pollutants from the estimated raw waste generation. The Agency estimates that capital costs above equipment in place for these plants will be $0.715 million ($1983) and total annual costs will be $0.499 million ($1983). The economic impact analysis concluded that there are no potential plant closures or employment effects associated with compliance with this regulation. If compliance costs were passed on to consumers, price increases would be no higher than 0.3 percent for lead battery products. There are no balance-of-trade effects. The Agency has determined that the effluent reduction benefits associated with compliance with BPT limitations justify the costs.

BAT - The BAT level represents the best economically achievable performance of plants of various ages, sizes, processes or other shared characteristics. As with BPT, where existing performance is uniformly inadequate, BAT may be transferred from a different subcategory or category. BAT may include feasible process changes or internal controls, even when not common industry practice.

In developing BAT, EPA has given substantial weight to the reasonableness of costs. The Agency considered the volume and nature of discharges, the volume and nature of discharges expected after application of BAT, the general environmental effects of the pollutants, and the costs and economic impacts of the required pollution control levels. Despite this consideration of costs, the primary determinant of BAT is still effluent reduction capability.

The direct dischargers are expected to move directly to compliance with BAT limitations from existing treatment because the flow reduction used to meet BAT limitations would allow the use of smaller -- and less expensive -- lime and settle equipment than would be used to meet BPT limitations without any flow reduction. The pollutants selected for regulation at BAT are: copper, lead, and iron.

Implementation of the BAT limitations will remove annually an estimated 115,600 kilograms (254,000 pounds) of toxic metals and 679,000 kilograms (1,494,000 pounds) per year of other pollutants from estimated raw waste generation at a capital cost, above equipment in place, of $0.819 million and a total annual cost of $0.510 million ($1983). The Agency projects no plant closures, employment impacts, or foreign trade effects and has determined that the BAT limitations are economically achievable.

NSPS - NSPS (new source performance standards) are based on the best available demonstrated technology (BDT), including process changes, in-plant controls, and end-of-pipe treatment technologies which reduce pollution to the maximum extent feasible.

EPA is establishing the best available demonstrated technology for the lead subcategory of the battery manufacturing category to be equivalent to BAT technology with the addition of filtration prior to discharge. The pollutants regulated at NSPS are copper, lead, iron, oil and grease, total suspended solids (TSS), and pH.

EPA estimates that a new direct discharge lead battery manufacturing plant having the industry average annual production level for discharging plants would generate a raw waste of 14,500 kilograms (31,800 pounds) per year of toxic pollutants. The NSPS technology would reduce the toxic pollutant discharge levels to 4.3 kilograms (9.5 pounds) per year. The capital investment cost for a new model lead battery manufacturing plant to install the NSPS technology is estimated to be $0.119 million, with annual costs of $0.069 million ($1983). EPA believes that NSPS will not constitute a barrier to entry for new sources, prevent major modifications to existing sources, or produce other adverse economic effects.

<u>PSES</u> - PSES (pretreatment standards for existing sources) are designed to prevent the discharge of pollutants which pass through, interfere with, or are otherwise incompatible with the operation of POTW. Pretreatment standards are technology-based and analogous to the best available technology for removal of toxic pollutants. EPA is promulgating PSES based on the application of technology equivalent to BAT, which consists of end-of-pipe treatment comprised of oil skimming where necessary, and lime precipitation and settling.

The Agency has concluded that the toxic metals regulated under these standards (copper and lead) pass through the POTW. The nationwide average percentage of these toxic metals removed by a well operated POTW meeting secondary treatment requirements is 58 percent for copper and 48 percent for lead, whereas the percentage that can be removed by a lead battery manufacturing direct discharger applying the best available technology economically achievable is expected to be over 99 percent. Accordingly, these pollutants pass through a POTW and are being regulated at PSES.

Implementation of the PSES will remove annually an estimated 1,488,400 kilograms (3,274,500 pounds) of toxic pollutants, and 8,743,600 kilograms (19,235,900 pounds) of other pollutants from estimated raw waste.

To comply with PSES, EPA estimates that total capital investment, above equipment in place, would be $7.11 million and that annual costs would be $4.07 million ($1983), including interest and depreciation. The Agency has concluded that PSES is economically achievable.

PSNS - Like PSES, PSNS (pretreatment standards for new sources) are established to prevent the discharge of pollutants which pass through, interfere with, or are otherwise incompatible with the operation of the POTW. New indirect dischargers, like new direct dischargers, have the opportunity to incorporate the best available demonstrated technologies.

This regulation establishes mass-based PSNS for the lead subcategory of the battery manufacturing category. The treatment technology basis for the PSNS being promulgated is identical to the treatment technology set forth as the basis for the NSPS being promulgated. The pollutants regulated under PSNS are copper and lead.

New source model plant costs were estimated for the lead subcategory. The total capital investment cost for a lead battery manufacturing plant with the industry average production level for discharging plants to install PSNS technology is $0.119 million with corresponding total annual costs of $0.069 million ($1983). This new lead battery manufacturing plant would generate a raw waste load of approximately 14,500 kilograms (31,800 pounds) per year of toxic pollutants and 84,900 kilograms (186,900 pounds) per year of other pollutants. Application of PSNS technology would reduce the toxic pollutant discharge to 4.3 kilograms (9.5 pounds) per year and the discharge of other pollutants to 42 kilograms (92 pounds) per year. EPA does not believe that PSNS will pose a barrier to entry for new indirect sources.

BCT - BCT effluent limitations for the lead subcategory are deferred pending adoption of the BCT cost test.

Nonwater Quality Environmental Impacts

Eliminating or reducing one form of pollution may cause other environmental problems. Sections 304(b) and 306 of the Act require EPA to consider the nonwater quality environmental impacts (including energy requirements). In compliance with these provisions, the Agency considered the effect of this regulation on air pollution, solid waste generation and energy consumption. The Administrator has determined that the impacts identified below are justified by the benefits associated with compliance with the limitations and standards.

Imposition of BPT, BAT, NSPS, PSES, and PSNS will not create any substantial air pollution problems because the wastewater treatment technologies required to meet these limitations and standards do not cause air pollution.

EPA estimates that battery manufacturing plants generated 18,960 kkg (87,000 tons) of solid wastes per year from manufacturing process operations, and an indeterminate amount of solid waste from wastewater treatment because of the variable technologies currently practiced. The solid wastes that would be generated at battery manufacturing plants by lime and settle treatment technologies are believed to be not hazardous under Section 3001 of the Resource Conservation and Recovery Act (RCRA). Only wastewater treatment sludge generated by sulfide precipitation technology, and wastewater treatment sludges containing mercury are likely to be hazardous under the regulations implementing subtitle C of RCRA.

EPA estimates that the achievement of BPT effluent limitations for the lead subcategory will result in a net increase in electrical energy consumption of approximately 0.40 million kilowatt-hours per year. The BAT effluent technology are projected to increase electrical energy consumption by 0.30 million kilowatt hours per year, slightly less than BPT. The energy requirements for NSPS and PSNS are estimated to be similar to energy requirements for BAT and PSES.

SECTION II

RECOMMENDATIONS

1. EPA has divided the battery manufacturing category into eight subcategories for the purpose of effluent limitations and standards. These subcategories are:

- A. Cadmium
- B. Calcium
- C. Lead
- D. Leclanche
- E. Lithium
- F. Magnesium
- G. Zinc
- H. Nuclear

2. These subcategories have been further subdivided into process elements specific to basic manufacturing operations within the subcategory, and the promulgated regulations are specific to these elements. This volume (Volume II) presents effluent limitations and standards for the lead subcategory (Subcategory C). Effluent limitations and standards for the other battery subcategories of the battery manufacturing category are presented in Volume I.

3. The following effluent limitations are promulgated for existing sources in the lead subcategory.

A. Subcategory C - Lead

(a) BPT Limitations

(1) Subpart C - Closed Formation - Double Fill, or Fill and Dump BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.86	0.45
Lead	0.19	0.090
Iron	0.54	0.27
Oil and Grease	9.00	5.40
TSS	18.45	8.78
pH	Within the range of 7.5 - 10.0 at all times	

(2) Subpart C - Open Formation - Dehydrated BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	20.99	11.05
Lead	4.64	2.21
Iron	16.13	6.74
Oil and Grease	221.00	132.60
TSS	453.05	215.47
pH	Within the range of 7.5 - 10.0 at all times	

(3) Subpart C - Open Formation - Wet BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.10	0.05
Lead	0.02	0.01
Iron	0.06	0.03
Oil and Grease	1.06	0.64
TSS	2.17	1.03
pH	Within the range of 7.5 - 10.0 at all times	

(4) Subpart C - Plate Soak
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.04	0.02
Lead	0.009	0.004
Iron	0.03	0.01
Oil and Grease	0.42	0.25
TSS	0.86	0.41
pH	Within the range of 7.5 - 10.at all times	

(5) Subpart C - Battery Wash (with Detergent)
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	1.71	0.90
Lead	0.38	0.18
Iron	1.08	0.55
Oil and Grease	18.00	10.80
TSS	36.90	17.55
pH	Within the range of 7.5 - 10.0 at all times	

(6) Subpart C - Battery Wash (Water Only) BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	1.12	0.59
Lead	0.25	0.12
Iron	0.71	0.36
Oil and Grease	11.80	7.08
TSS	24.19	11.51
pH	Within the range of 7.5 - 10.0 at all times	

(7) Subpart C - Direct Chill Lead Casting BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.0004	0.0002
Lead	0.00008	0.00004
Iron	0.0002	0.0001
Oil and Grease	0.004	0.002
TSS	0.008	0.003
pH	Within the range of 7.5 - 10.at all times	

(8) Subpart C - Mold Release Formulation BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.011	0.006
Lead	0.002	0.001
Iron	0.007	0.004
Oil and Grease	0.120	0.072
TSS	0.246	0.117
pH	Within the range of 7.5 - 10.0 at all times	

(9) Subpart C - Truck Wash BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Copper	0.026	0.014
Lead	0.005	0.002
Iron	0.016	0.008
Oil and Grease	0.280	0.168
TSS	0.574	0.273
pH	Within the range of 7.5 - 10.at all times	

(10) Subpart C - Laundry
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.21	0.11
Lead	0.05	0.02
Iron	0.13	0.07
Oil and Grease	2.18	1.31
TSS	4.47	2.13
pH	Within the range of 7.5 - 10.0 at all times	

(11) Subpart C - Miscellaneous Wastewater Streams
BPT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.81	0.43
Lead	0.18	0.09
Iron	0.51	0.26
Oil and Grease	8.54	5.12
TSS	17.51	8.33
pH	Within the range of 7.5 - 10.0 at all times	

There shall be no discharge allowance for process wastewater pollutants from any battery manufacturing operation other than those battery manufacturing operations listed above.

(b) BAT Limitations

(1) Subpart C - Open Formation - Dehydrated
BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	3.19	1.68
Lead	0.71	0.34
Iron	2.02	1.02

(2) Subpart C - Open Formation - Wet
BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.100	0.053
Lead	0.022	0.010
Iron	0.06	0.03

(3) Subpart C - Plate Soak
BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.039	0.021
Lead	0.008	0.004
Iron	0.030	0.010

(4) Subpart C - Battery Wash (Detergent) BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.86	0.45
Lead	0.19	0.09
Iron	0.54	0.27

(5) Subpart C - Direct Chill Lead Casting BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.0004	0.0002
Lead	0.00008	0.00004
Iron	0.0002	0.0001

(6) Subpart C - Mold Release Formulation BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.011	0.006
Lead	0.002	0.001
Iron	0.007	0.003

(7) Subpart C - Truck Wash
BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Copper	0.026	0.014
Lead	0.005	0.002
Iron	0.016	0.008

(8) Subpart C - Laundry
BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.21	0.11
Lead	0.05	0.02
Iron	0.13	0.07

(9) Subpart C - Miscellaneous Wastewater Streams
BAT Effluent Limitations

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.58	0.31
Lead	0.13	0.06
Iron	0.37	0.19

There shall be no discharge allowance for process wastewater pollutants from any battery manufacturing operation other than those battery manufacturing operations listed above.

4. The following standards are promulgated for new sources.

A. Subcategory C - Lead

(1) Subpart C - Open Formation - Dehydrated - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	2.15	1.02
Lead	0.47	0.21
Iron	2.01	1.02
Oil and Grease	16.80	16.80
TSS	25.20	20.16
pH	Within the limits of 7.5 - 10.0 at all times	

(2) Subpart C - Open Formation - Wet - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.067	0.032
Lead	0.014	0.006
Iron	0.063	0.032
Oil and Grease	0.53	0.53
TSS	0.80	0.64
pH	Within the limits of 7.5 - 10.0 at all times	

(3) Subpart C - Plate Soak - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.026	0.012
Lead	0.005	0.002
Iron	0.025	0.012
Oil and Grease	0.21	0.21
TSS	0.32	0.25
pH	Within the limits of 7.5 - 10.0 at all times	

(4) Subpart C - Battery Wash (Detergent) - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.576	0.274
Lead	0.126	0.058
Iron	0.540	0.274
Oil and Grease	4.50	4.50

TSS	6.75	5.40
pH	Within the limits of 7.5 - 10.0 at all times	

(5) Subpart C - Direct Chill Lead Casting - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.000256	0.000122
Lead	0.000056	0.000026
Iron	0.000240	0.000122
Oil and Grease	0.0020	0.0020
TSS	0.0030	0.0024
pH	Within the limits of 7.5 - 10.0 at all times	

(6) Subpart C - Mold Release Formulation - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.0077	0.0037
Lead	0.0017	0.0008
Iron	0.0072	0.0037
Oil and Grease	0.060	0.060
TSS	0.090	0.072
pH	Within the limits of 7.5 - 10.0 at all times	

(7) Subpart C - Truck Wash - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Copper	0.006	0.003
Lead	0.001	0.0007
Iron	0.006	0.003
Oil and Grease	0.050	0.050
TSS	0.075	0.060
pH	Within the limits of 7.5 - 10.0 at all times	

(8) Subpart C - Laundry - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.14	0.07
Lead	0.03	0.01
Iron	0.13	0.07
Oil and Grease	1.09	1.09
TSS	1.64	1.31
pH	Within the limits of 7.5 - 10.0 at all times	

(9) Subpart C - Miscellaneous Wastewater Streams - NSPS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.39	0.19
Lead	0.085	0.039
Iron	0.37	0.19
Oil and Grease	3.07	3.07
TSS	4.61	3.69
pH	Within the limits of 7.5 - 10.0 at all times	

There shall be no discharge allowance for process wastewater pollutants from any battery manufacturing operation other than those battery manufacturing operations listed above.

5. The following pretreatment standards are promulgated for existing sources.

A. Subcategory C - Lead

(1) Subpart C - Open Formation - Dehydrated - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	3.19	1.68
Lead	0.71	0.34

(2) Subpart C - Open Formation - Wet - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.100	0.053
Lead	0.022	0.010

(3) Subpart C - Plate Soak - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.039	0.021
Lead	0.008	0.004

(4) Subpart C - Battery Wash - Detergent - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.86	0.45
Lead	0.19	0.09

(5) Subpart C - Direct Chill Lead Casting - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.0004	0.0002
Lead	0.00008	0.00004

(6) Subpart C - Mold Release Formulation - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.011	0.006
Lead	0.002	0.001

(7) Subpart C - Truck Wash - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Copper	0.026	0.014
Lead	0.005	0.002

(8) Subpart C - Laundry - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.21	0.11
Lead	0.05	0.02

(9) Subpart C - Miscellaneous Wastewater Streams - PSES

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.58	0.31
Lead	0.13	0.06

There shall be no discharge allowance for process wastewater pollutants from any battery manufacturing operation other than those battery manufacturing operations listed above.

6. The following pretreatment standards are promulgated for new sources.

A. Subcategory C - Lead

(1) Subpart C - Open Formation - Dehydrated - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	2.15	1.02
Lead	0.47	0.21

(2) Subpart C - Open Formation - Wet - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.067	0.032
Lead	0.014	0.006

(3) Subpart C - Plate Soak - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.026	0.012
Lead	0.005	0.002

(4) Subpart C - Battery Wash - Detergent - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.576	0.274
Lead	0.126	0.058

(5) Subpart C - Direct Chill Lead Casting - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.000256	0.000122
Lead	0.000056	0.000026

(6) Subpart C - Mold Release Formulation - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.007	0.0037
Lead	0.0017	0.0008

(7) Subpart C - Truck Wash - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Copper	0.006	0.003
Lead	0.001	0.0007

(8) Subpart C - Laundry - PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.14	0.07
Lead	0.03	0.01

(9) Subpart C - Miscellaneous Wastewater Streams -PSNS

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Copper	0.39	0.19
Lead	0.085	0.039

There shall be no discharge allowance for process wastewater pollutants from any battery manufacturing operations other than those battery manufacturing operations listed above.

7. Effluent limitations based on the best conventional pollutant control technology are reserved at this time.

SECTION III

INTRODUCTION

This section provides an overview of the legal background of the Clean Water Act, and of the technical background of the battery category. Volumes I and II include general information for the entire category in this section. Volume I also includes a brief technical description of the cadmium, calcium, Leclanche, lithium, magnesium, and zinc subcategories whereas only the lead subcategory is discussed in Volume II.

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 12 ERC 1833 (D.D.C. 1979), modified by orders dated October 26, 1982, August 2, 1983 and January 6, 1984. 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.

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). The cost methodology for BCT has not been promulgated and BCT is presently deferred. 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 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. In addition to existing and plant supplied information (via dcp), data were obtained through a sampling program conducted 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 used 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 on 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 the subcategorization discussion, but have not been considered in the battery documents. 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 the battery documents.

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 on dcp responses and 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 Battery Documents*
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

* All subcategories except for lead are discussed in detail in Volume I and the lead subcategory is discussed in Volume II.

As 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 Sections 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 technologies 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 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. 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 plants 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 battery manufacturing were gathered from literature studies, previous industry studies by the Agency, plant surveys and evaluations, 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 XV. 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 initial 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 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 companies were in other business areas.

For clarification, the following terminology is used throughout the battery manufacturing documents. Battery manufacturing sites are physical locations where battery manufacturing processes occur. Battery plants are locations where subcategory-specific battery manufacturing processes occur. Battery facilities are locations where final battery type products or their components are produced and is primarily used for economic analysis of the category. In the survey, some plants responded with 1977 or 1978 data, and some provided 1976 data although production has subsequently ceased. Table III-1 (page 63) summarizes the survey responses received in terms of number of plants that 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 site owned or operated by the company. Also, some sites manufacture batteries in more than one subcategory; four are active in three subcategories and nine are active in two subcategories. Due to changes in ownership and changes in production lines, the number of companies and the number of plants and sites active in the category often vary. The result is that about 230 sites are currently included in this category. All information received was reviewed and evaluated, and will be discussed as appropriate in subsequent sections.

The second phase of the data collection effort included visiting selected plants, for screening and verification sampling of wastewaters from battery manufacturing operations. The dcp served as the major source in the selection of plants for visitation and sampling. Specific criteria used for site selection 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 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.

Prior to proposal forty-eight plants were visited and a wastewater sampling program was conducted at twenty-four 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 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.

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 and of the overall sampling program results are described in Section V of this document.

After proposal, EPA made a second intensive study of lead battery manufacturing (lead subcategory), and foliar battery manufacturing (Leclanche subcategory). Seventeen additional lead plants were visited and five were sampled. One foliar plant was also visited. Plant supplied data from 65 lead plants was updated using an industry survey form. This additional data is reported in Section V, (Volume I for the Leclanche subcategory and Volume II for the Lead subcategory).

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 manufacturers' research and 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 and information in 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 that it was 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 subcategory discussed in the two volumes.

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 where 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 came 12 years after the discovery of the galvanic cell by Galvani, and 2000 years after 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 experiments, Davy, and then Faraday, used galvanic cells to carry out electrolysis studies. In 1836 Daniell invented the cell which now bears 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 1880s 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 manufactured 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 strips. 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, tens of thousands of which are in use. Huge development 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 68), 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, and the Edison battery (Fe/NiOOH) and the zinc-nickel oxide battery.

Battery Definitions and Terminology - 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 these documents the marketed end product is usually referred to as a battery. Manufacturing flow charts and construction diagrams reveal the actual assembly details.

In the battery documents, 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 where 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>, sometimes called the <u>negative plate</u>, a <u>cathode</u>, also called the <u>positive plate</u>, and <u>electrolyte</u>. The anode and cathode are referred to by the general term <u>electrodes</u>. One or both electrodes consist of a <u>support</u> or <u>grid</u> which serves as a mechancial support and <u>current collector</u>, and the active material which actually undergoes electrochemical reaction to produce the <u>current</u> and <u>voltage</u> 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 <u>electrode system</u>. For convenience, in this document as well as in many publications, the terms cathode or anode are used to designate the <u>cathode system</u> or the <u>anode system</u>.

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

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, 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-load 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 69) illustrates how these measures of 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 be useful however, in considering groups for which the general purpose and primary performance requirements are similar. Such groups are shown in Table III-2 (page 64).

The requirements for a flashlight battery are: low cost, long shelf life, suitability for intermittent use, and 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.

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 the overall cost of launching a satellite or travel to a remote location overshadows 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 is 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 over 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 also become secondary considerations in both of these applications.

Battery Function and Manufacture

The extremely varied requirements outlined above have led to the 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 the electrochemistry of batteries, battery construction, and battery manufacturing are presented to help orient the reader.

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, and 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 nonelectrochemical 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 having 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 (page 65) show the reactions as they are used in practical cells for delivery of power. In those cells that are rechargeable, charging reverses the direction of the reaction as written in the tables.

Most of the battery systems currently produced are based on aqueous electrolytes. However, lithium and thermal batteries, and at least one magnesium cell, have nonaqueous 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 pyrotechnic 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, as long as the electrolytes are matched and the overall cell reaction can be balanced at electrical neutrality. As examples:

Leclanche:

anode: $Zn \longleftrightarrow Zn^{+2} + 2e$ (acid)

cathode: $2e + 2MnO_2 + 2NH_4Cl + Zn^{+2} \longleftrightarrow MN_2O_3 + H_2O + Zn(NH_3)_2Cl_2$(acid)

cell: $Zn + 2MnO_2 + 2NH_4Cl \longleftrightarrow Mn_2O_3 + H_2O + Zn(NH_3)_2Cl_2$

Alkaline Manganese:

anode: $Zn + 2OH^- \longleftrightarrow Zn(OH)_2 + 2e$ (alkaline)

cathode: $e + MnO_2 + H_2O \longleftrightarrow MnOOH + OH^-$ (alkaline)

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

cell: $Zn + MnO_2 + 2H_2O \longleftrightarrow Zn(OH)_2 + Mn(OH)_2$

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 prevent 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 leads 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 compatibility of separators and electrolytes is an important factor in battery design.

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 the 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 25 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 batteries, 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 accommodated 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 that 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 are 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 depleted of ions required for electrode reaction. For instance, at the negative plate of a lead-acid battery, sulfate ions are required for the reaction:

$$Pb + SO_4 \text{ <---> } PbSO_4 + 2e$$

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 70-79) are drawings or cutaway views of these 10 batteries. Figures III-13 through III-20 (pages 80-87) 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, and then the paste is applied to a support structure and cured.

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 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 above. 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, is considered 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 physically arranged, 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.

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 to 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 is considered part of battery manufacturing usually as an ancillary operation.

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 (mDNB), 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) is considered an 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 positioned, electrolyte is applied to it before the next electrode is placed. When the battery is completed the entire assembly is sandwiched between two thin aluminum sheets. Assembly is completely automated. The resulting six-volt battery is about three inches by four inches by three-sixteenths of an inch thick and has high specific power and power density. Shelf life is several years and operating lifetime depends on drain rate.

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 about 250 plants operated by about 130 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 33 thousand workers. As Figure III-21 (page 88) shows, the value of industry products 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 the decline and phase - 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 plants are fairly new with over half reported to have been built in the past twenty years. Most have been modified even more recently. Figure III-22 (page 89) displays where battery plants are located throughout the U.S. and within EPA regions.

Plants commonly manufacture a variety of cells and batteries differing in size, shape, and performance characteristics. Further, a significant 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 plants currently produce cells or batteries using two or more different anode materials and therefore are considered in two or more subcategories. Some battery manufacturing plants purchase finished cell components and assemble the final battery products without performing all of the manufacturing process steps on-site. Other plants 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 following 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 the 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 (page 66). 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. Table III-6 (page 67) summarizes the characteristics of plants manufacturing batteries in each of the groups discussed in the battery documents based on anode and electrolyte. The lead subcategory is discussed below.

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 186 battery manufacturing plants of which about 146 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 plants 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 in this subcategory 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 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 18,745. Most of the plants employing fewer than 10 employees were found to be battery assemblers who purchased charged or uncharged plates produced in other plants. 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 90 and 91).

With the exception of lead-acid reserve batteries (which are electroformed and are reported to be 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; this accounted for over 18 percent of all lead acid batteries produced. Twenty-seven plants reported producing damp batteries, which account for 9.3 percent of the subcategory total, or 121,000 metric tons (136,000 tons). Contacts with battery manufacturers have indicated a substantial reduction in dehydrated battery manufacture since 1976 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, 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, laboratories, casting operations, and personal hygiene where process materials are removed by washing.

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 6580 l/hr (1,740 gal/hr) and a median discharge rate of 1,640 l/hr (430 gal/hr). When normalized on the basis of the total amount of lead used in battery manufacture, these discharge flows vary between 0 and 78 l/kg (9.5 gal/lb) with an average of 4.280 l/kg (0.521 gal/lb). Over 60 percent of lead subcategory plants discharge wastewater to POTW. The wastewater from these plants 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 to provide settling to remove particulates and precipitated lead. In-process treatment and reuse of specific waste streams is also common.

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 occurred 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 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 has 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 have 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 are 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 are 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 growth in 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 where demand for specific battery types is not strong to another is more likely than plant closings.

TABLE III-1

SURVEY SUMMARY

SUBCATEGORY	NUMBER OF PLANTS (Information Received)	NUMBER OF PLANTS (Currently Active)
Cadmium	13	10
Calcium	3	3
Lead	186*	167*
Leclanche	20	19
Lithium	7	7
Magnesium	8	8
Nuclear	1	0
Zinc	17	16
Totals	255	228

Total Number of Plant Sites in Category - 230.

*Includes plate manufacturers and assemblers.

TABLE III-2

BATTERY GENERAL PURPOSES AND APPLICATIONS

	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 PBXs
6.	Secondary voltage standard	regulated power supplies

TABLE III-3

ANODE HALF-CELL REACTIONS (electrolyte)

$Cd + 2OH^-$ <---> $Cd(OH)_2 + 2e$ (alkaline)
Ca <---> $Ca^{+2} + 2e$ (nonaqueous inorganic)
$Pb + H_2SO_4$ <---> $PbSO_4 + 2H^+ + 2e$ (acidic)
Zn <---> $Zn^{+2} + 2e$ (acidic)
Li <---> $Li^+ + e$ (molten salt, organic, nonaqueous inorganic)
Mg <---> $Mg^{+2} + 2e$ (sea water)
$Zn + 2OH^-$ <---> $Zn(OH)_2 + 2e$ (alkaline)

TABLE III-4

CATHODE HALF-CELL REACTIONS (electrolyte)

$e + NiOOH + H_2O$ <---> $Ni(OH)_2 + OH^-$ (alkaline)
$4e + Ag_2O_2 + 2H_2O$ <---> $2Ag + 4OH^-$ (alkaline)
$2e + Ag_2O + H_2O$ <---> $2Ag + 2OH^-$ (alkaline)
$2e + HgO + H_2O$ <---> $Hg + 2OH^-$ (alkaline)
$2e + PbO_2 + SO_4^{-2} + 4H^+$ <---> $PbSO_4 + 2H_2O$ (acid)
$2e + 2MnO_2 + 2NH_4Cl + Zn^{+2}$ <---> $Mn_2O_3 + H_2O + Zn(NH_3)_2Cl_2$ (acid)
$2e + 2AgCl + Zn^{+2}$ <---> $2Ag + ZnCl_2$ (acid)
$e + TiS_2 + Li^+$ <---> $TiS_2{:}Li$ (propylene carbonate)
$2e + 2SO_2$ <---> $S_2O_4^{-2}$ (acetonitrile)
$4e + 2SOCl_2 + 4\ Li^+$ <---> $4\ LiCl + (SO)_2$ (thionyl chloride)
$2e + I_2 + 2\ Li^+$ <---> $2\ LiI$ [poly(2 vinyl)propylene]
$2e + PbI_2 + 2Li^+$ <---> $2\ LiI + Pb$ (nonaqueous inorganic)
$2e + PbS + 2Li^+$ <---> $Li_2S + Pb$ (nonaqueous inorganic)
$e + MnO_2 + H_2O$ <---> $MnOOH + OH^-$ (alkaline)
$e + MnOOH + H_2O$ <---> $Mn(OH)_2 + OH^-$ (alkaline)
$8e + m\text{-}C_6H_4(NO_2)_2 + 6NH_4^+ + Mg^{+2}$ <---> $m\text{-bis-}C_6H_4(NHOH)_2$
$+ 6NH_3 + Mg(OH)_2$ (ammonia)
$2e + PbCl_2$ <---> $Pb + 2Cl^-$ (sea water)
$e + CuCl$ <---> $Cu + Cl^-$ (sea water)
$e + AgCl$ <---> $Ag + Cl^-$ (sea water)
$4e + O_2 + 2H_2O$ <---> $4OH^-$ (alkaline)

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. Numbers shown are sums of provided data. Because response to the raw materials questions was incomplete, actual consumption will be higher by 10 to 20 percent.

TABLE III-6

BATTERY MANUFACTURING CATEGORY SUMMARY
(TOTAL DATA BASE)

Subcategory	Batteries Manufactured	Number of Plants	Estimated Total Annual Production kkg	(tons)	Estimated Total Number of Employees	Discharges Direct	POTW	Zero	Total Process Wastewater Flow l/yr (10^6)	[gal/yr (10^6)]
Cadmium	Nickel-Cadmium Silver Cadmium Mercury Cadmium	13	5,250	(5,790)	2,500	5(4)[1]	4	4(5)[1]	748	(198)
Calcium	Thermal	3	<23	(<25)	240		2	1	0.13	(0.034)
Lead	Lead Acid	186	1,300,000	(1,430,000)	18,745	12	117	57	7,106	(1,877)
Leclanche	Carbon Zinc Carbon Zinc, Air Depolarized Silver Chloride-Zinc	20	108,000	(119,000)	4,200	0	8	12	16.7	(4.41)
Lithium	Lithium Thermal	7	<23	(<25)	400	1	4	2	0.36	(0.095)
Magnesium	Magnesium Carbon Magnesium Reserve Thermal	8	1,220	(1,340)	350	1	3	4	3.91	(1.03)
Zinc	Alkaline Manganese Silver Oxide-Zinc Mercury Zinc Carbon Zinc-Air Depolarized Nickel Zinc	17	23,000	(25,000)	4,680	3	11	3	60.3	(15.9)
	TOTALS	254[2]	1,437,516	(1,581,180)	31,115	22(21)	149	83(84)	7,935.40	(2,096.469)

NOTES:

[1] One direct discharge plant changed to zero discharge after data was collected.

[2] Total does not include nuclear subcategory (1 plant).

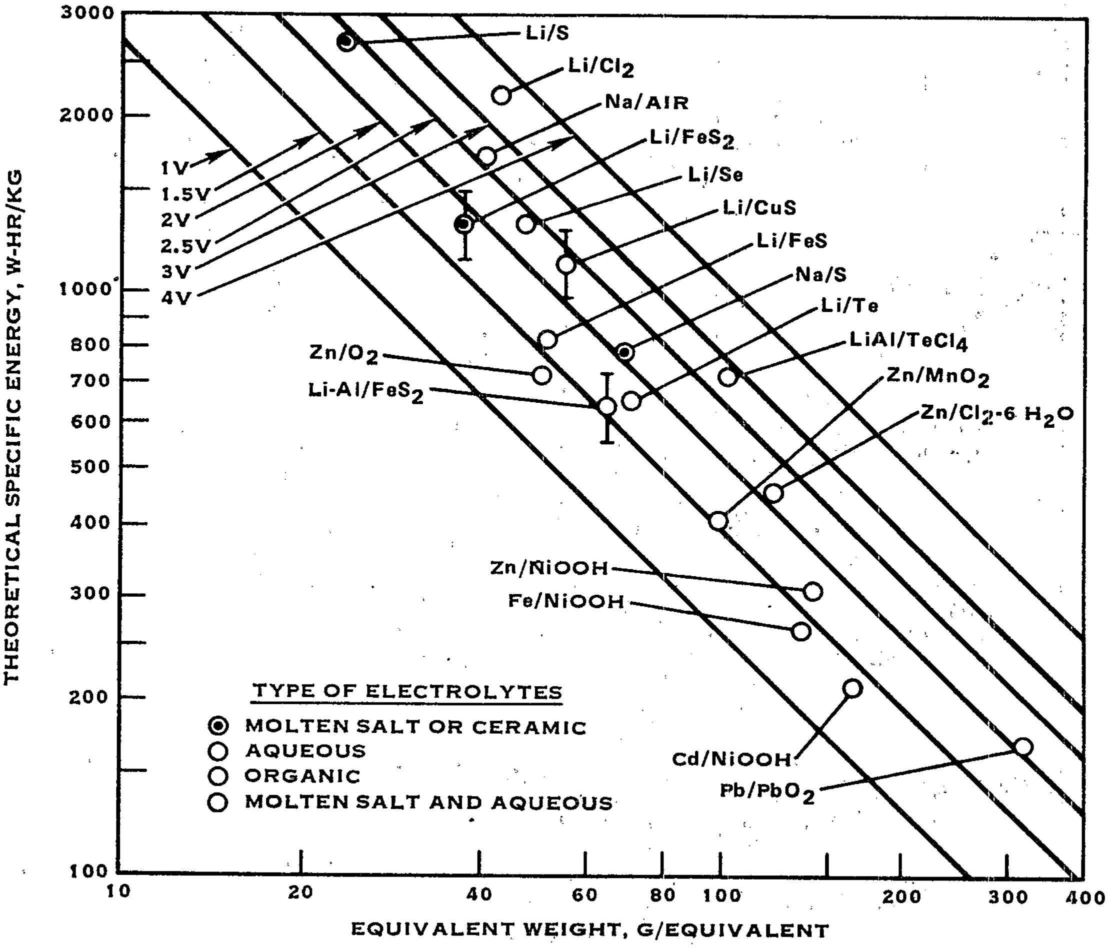


FIGURE III-1
THEORETICAL SPECIFIC ENERGY AS A FUNCTION OF EQUIVALENT WEIGHT AND CELL VOLTAGE FOR VARIOUS ELECTROLYTIC COUPLES

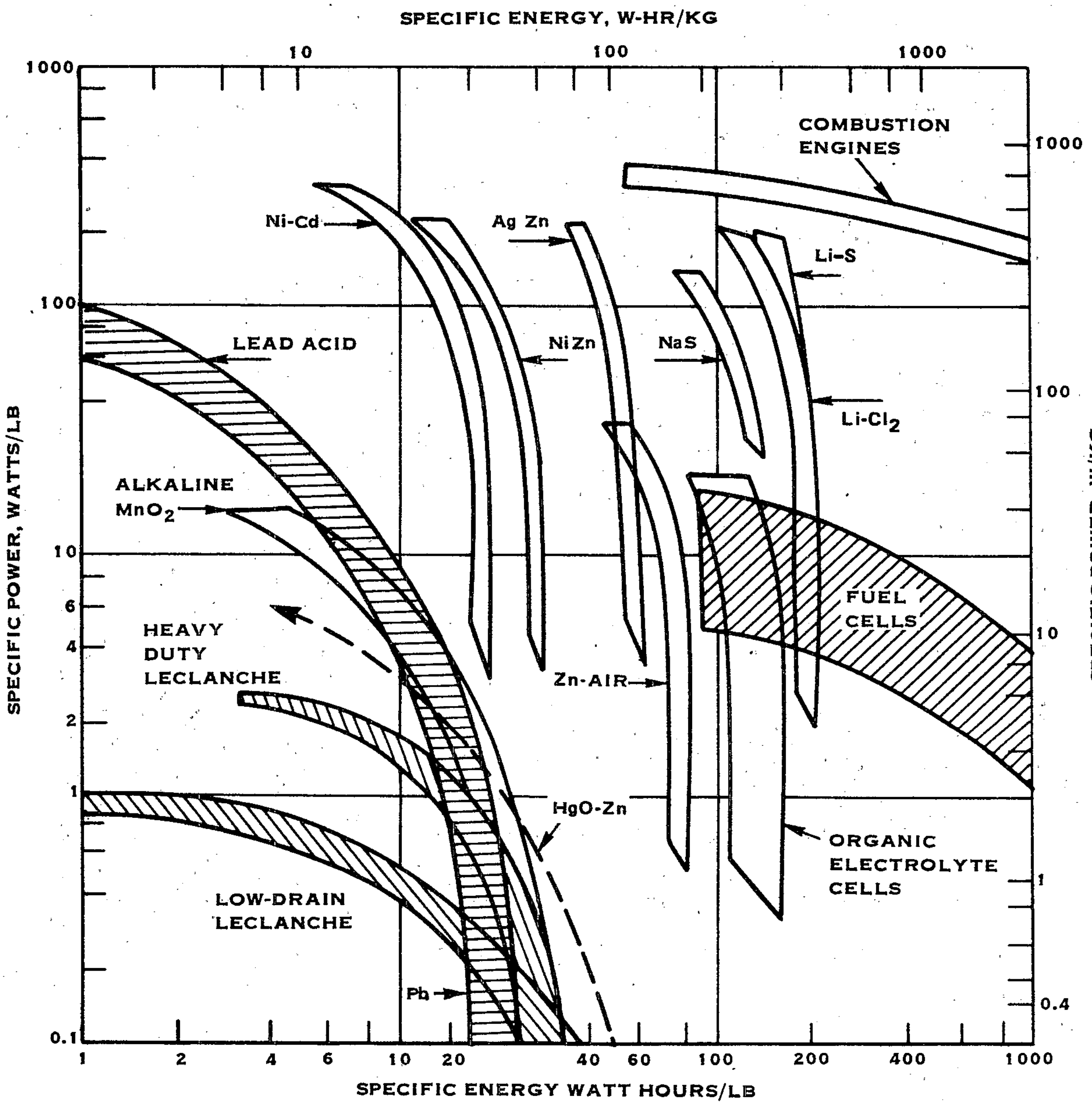


FIGURE III-2
PERFORMANCE CAPABILITY OF VARIOUS BATTERY SYSTEMS

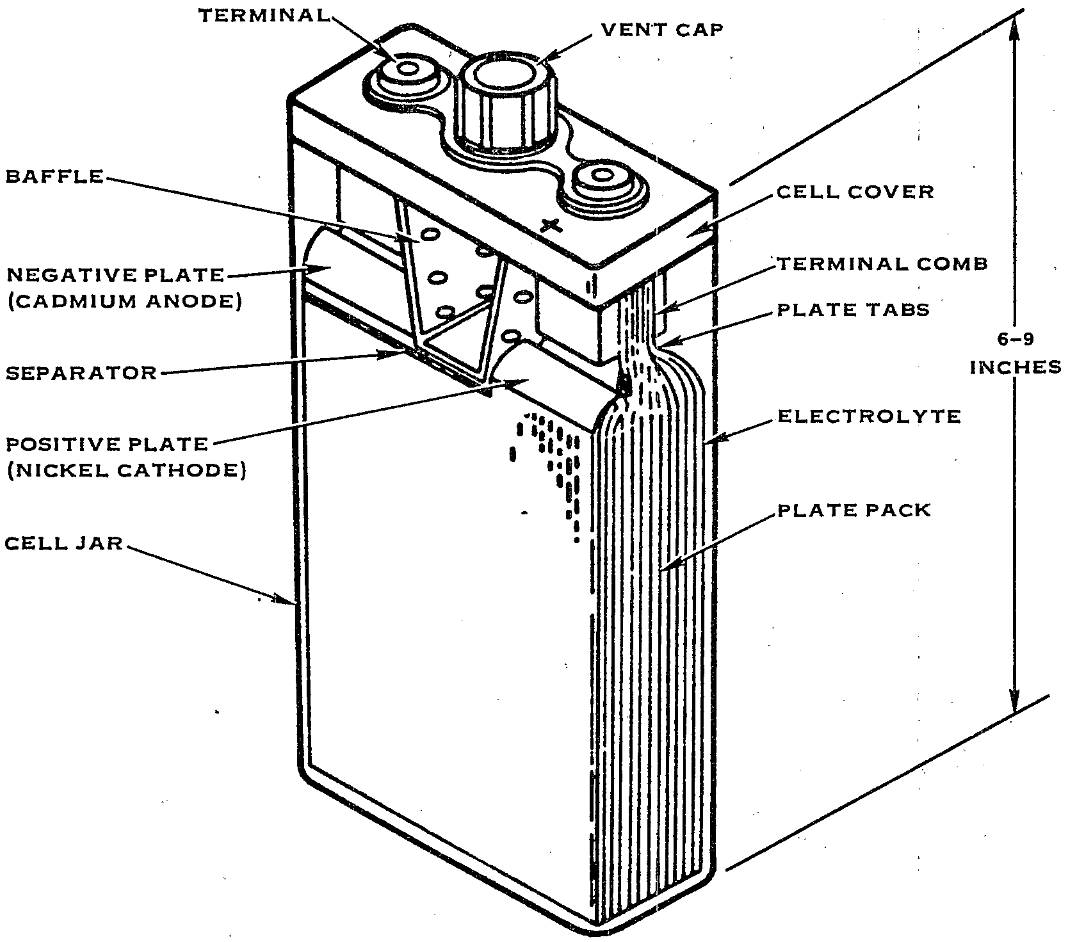


FIGURE III-3
CUTAWAY VIEW OF AN IMPREGNATED SINTERED PLATE NICKEL-CADMIUM CELL
(SIMILAR IN PHYSICAL STRUCTURE TO SOME
SILVER OXIDE-ZINC AND NICKEL-ZINC CELLS)

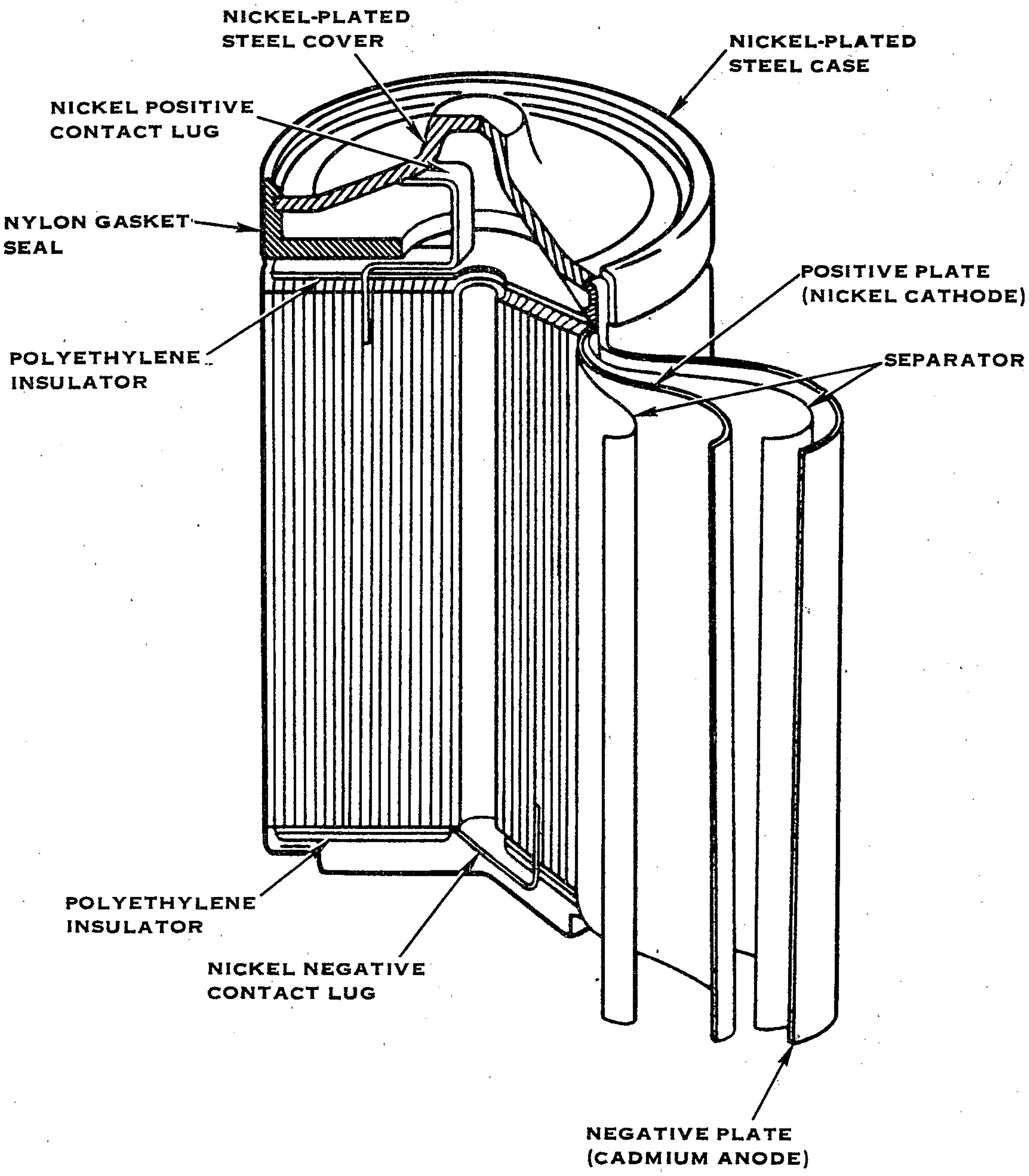


FIGURE III-4
CUTAWAY VIEW OF A CYLINDRICAL NICKEL-CADMIUM BATTERY (SIMILAR IN PHYSICAL STRUCTURE TO CYLINDRICAL LEAD ACID BATTERIES)

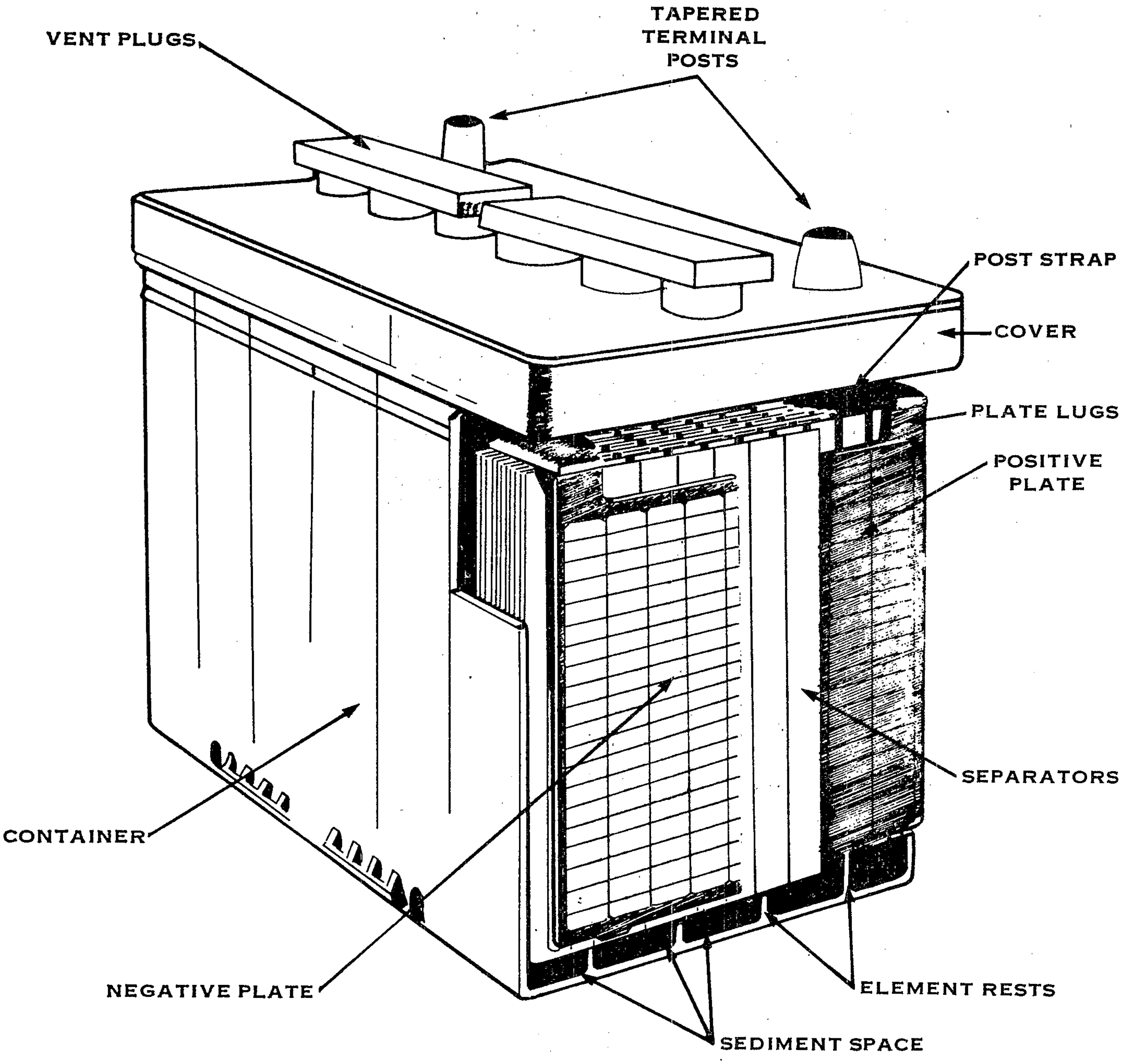


FIGURE III-5
CUTAWAY VIEW OF LEAD ACID STORAGE BATTERY

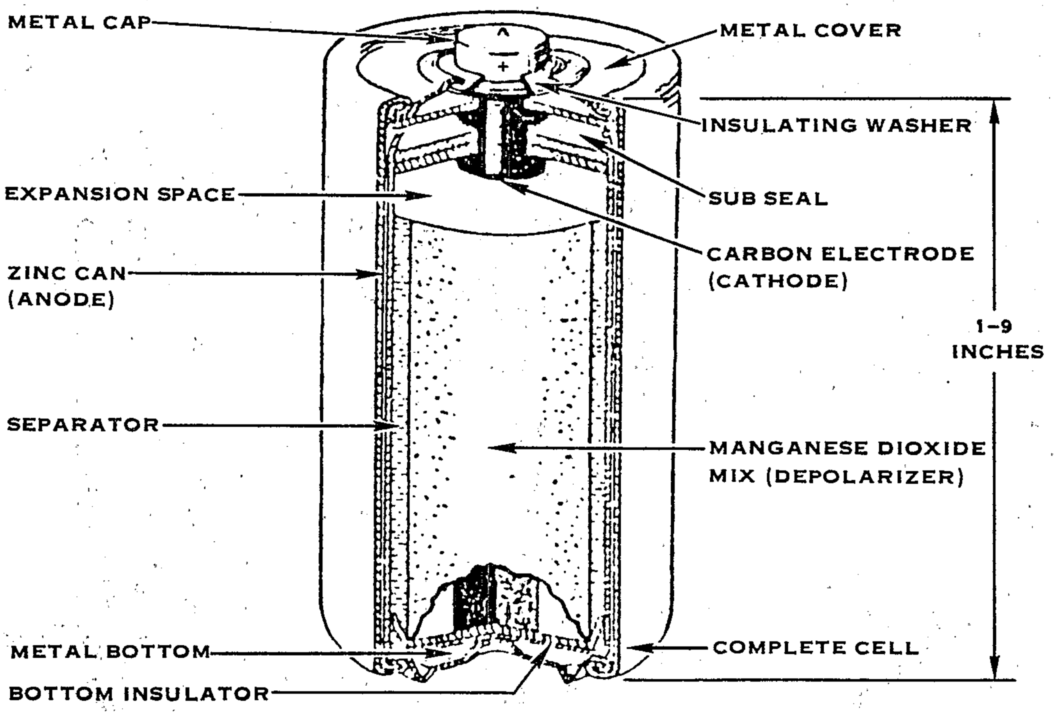


FIGURE III-6
CUTAWAY VIEW OF A CYLINDRICAL LECLANCHE CELL (SIMILAR IN PHYSICAL STRUCTURE TO SOME CARBON-ZINC-AIR AND SILVER CHLORIDE-ZINC DRY CELLS)

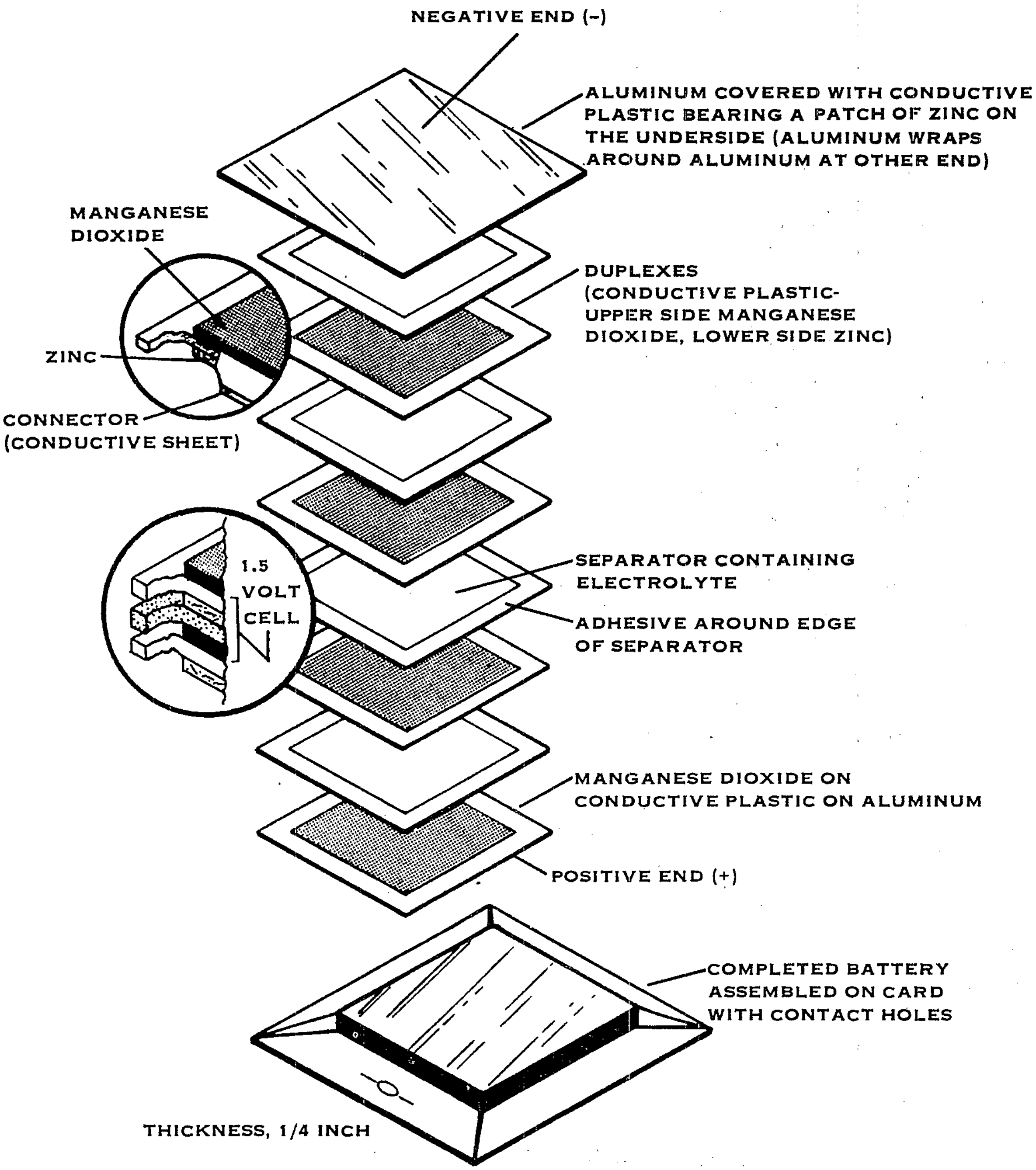
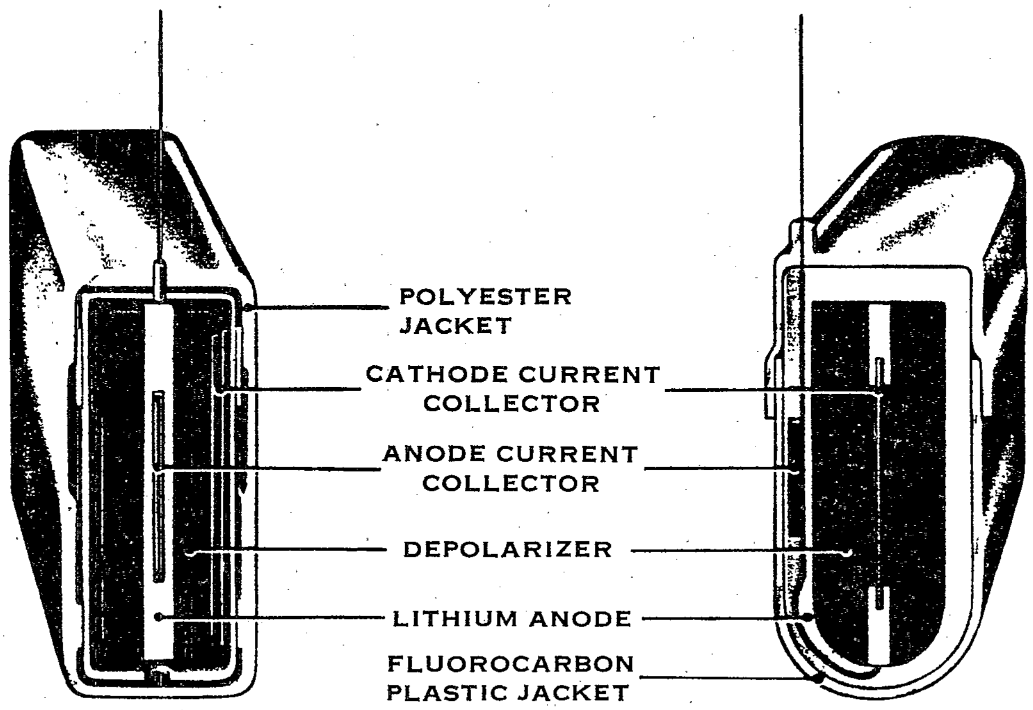


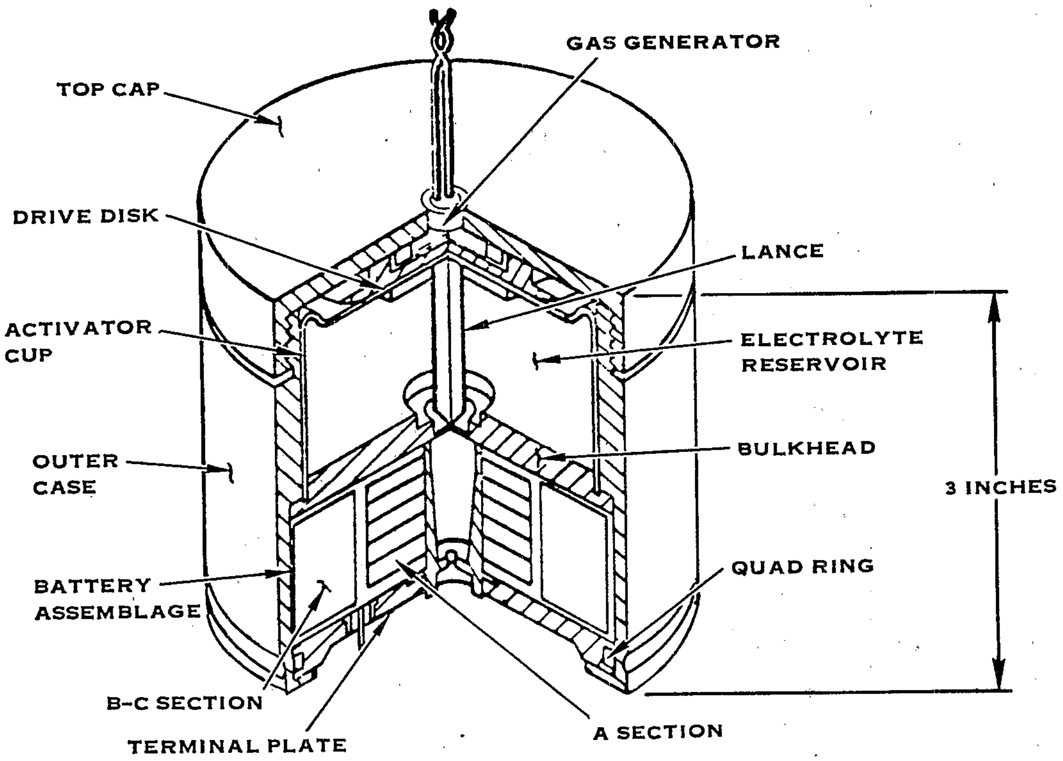
FIGURE III-7
EXPLODED VIEW OF A FOLIAR LECLANCHE BATTERY USED IN FILM PACK



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



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)

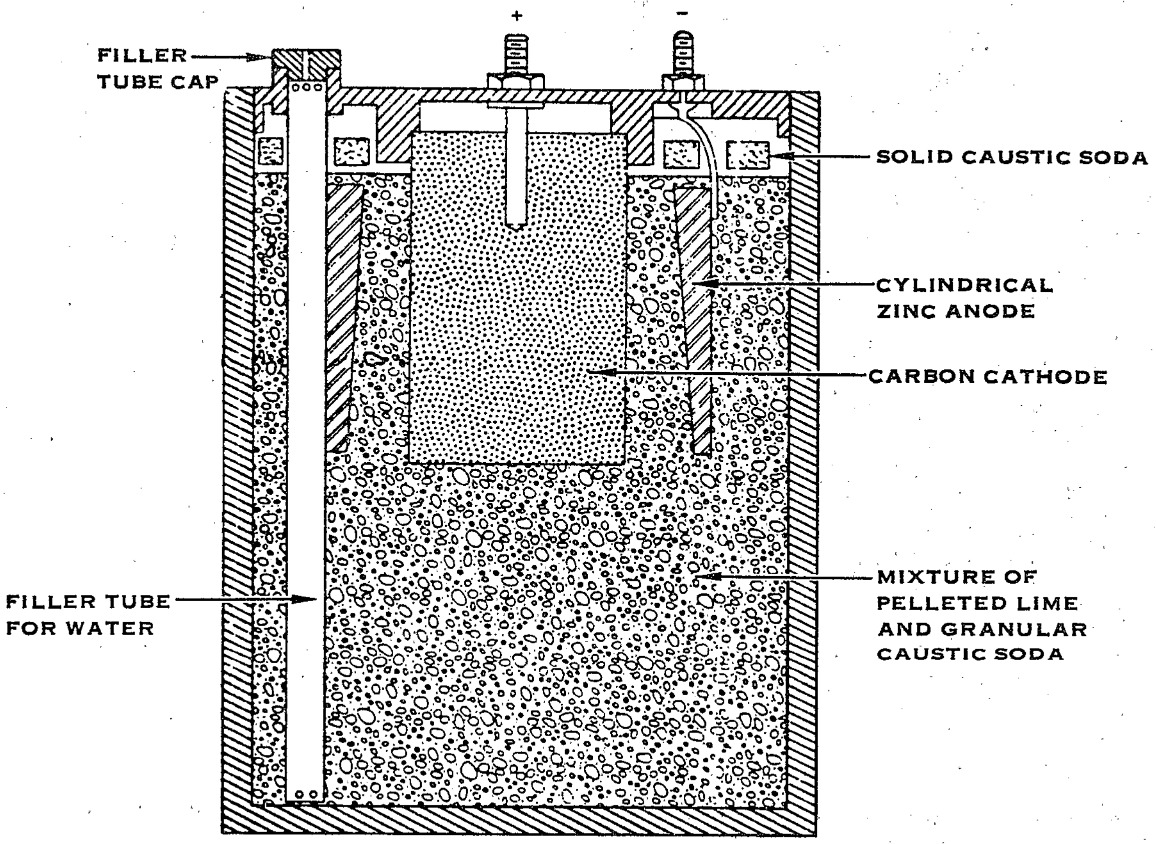


FIGURE III-10
CUTAWAY VIEW OF A CARBON-ZINC-AIR CELL

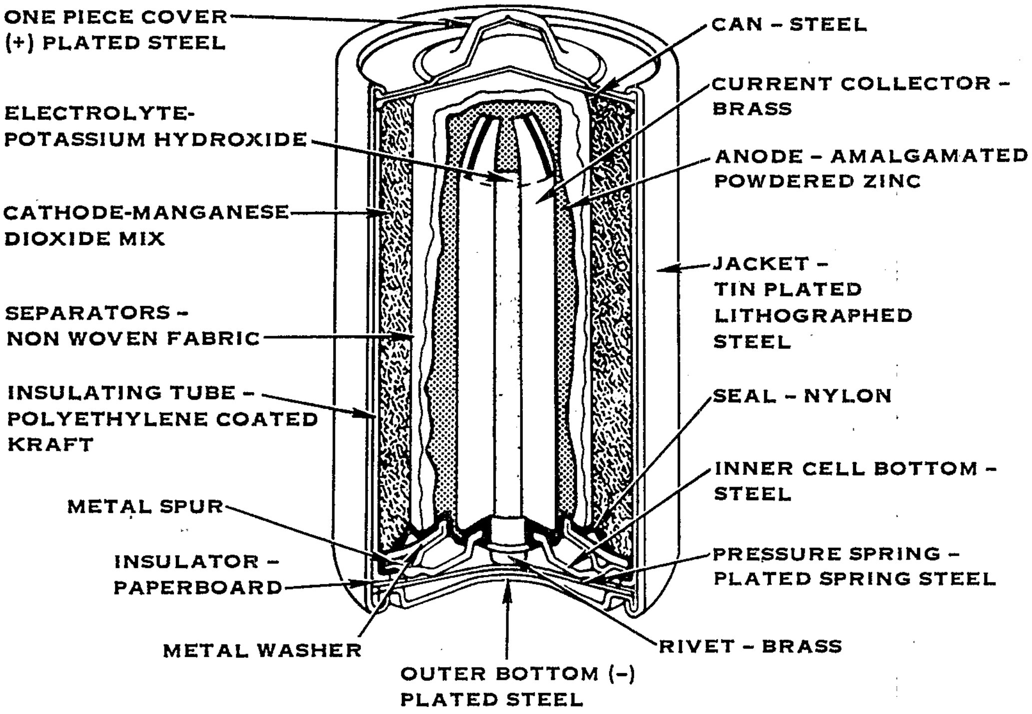


FIGURE III-11
CUTAWAY VIEW OF AN ALKALINE-MANGANESE BATTERY
(SIMILAR IN PHYSICAL STRUCTURE TO CYLINDRICAL
MERCURY-ZINC BATTERIES)

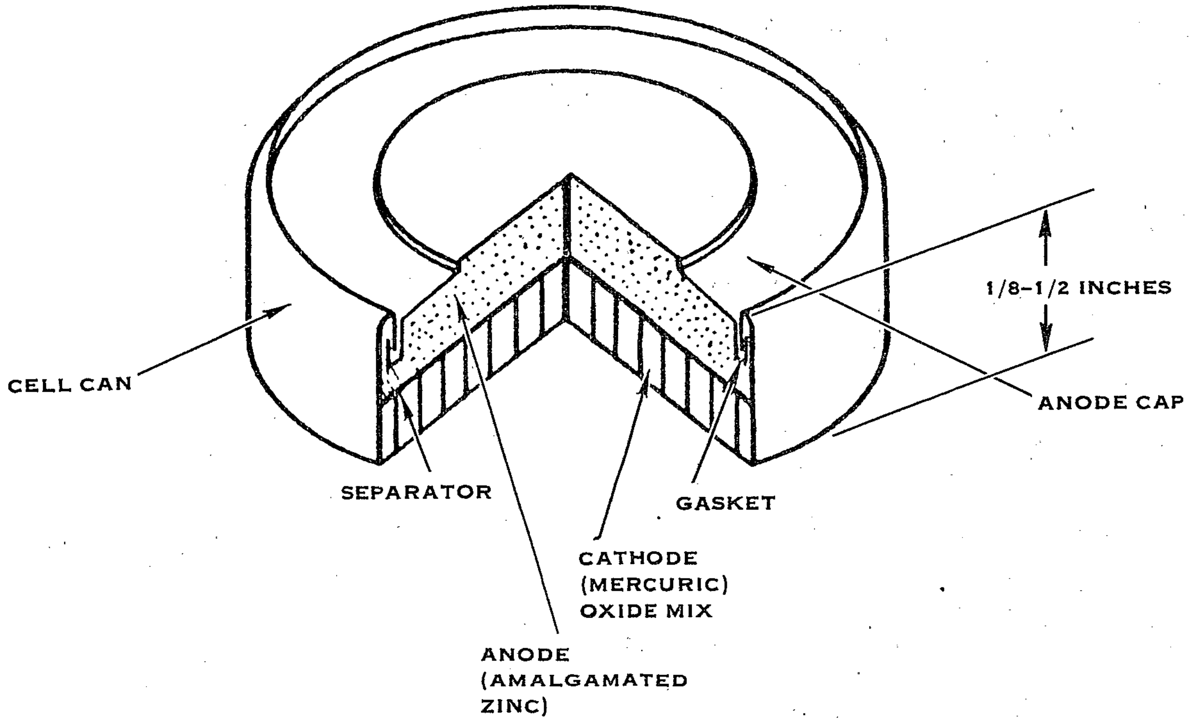


FIGURE III-12
CUTAWAY VIEW OF A MERCURY-ZINC (RUBEN) CELL (SIMILAR IN PHYSICAL STRUCTURE TO ALKALINE-MANGANESE AND SILVER OXIDE-ZINC BUTTON CELLS)

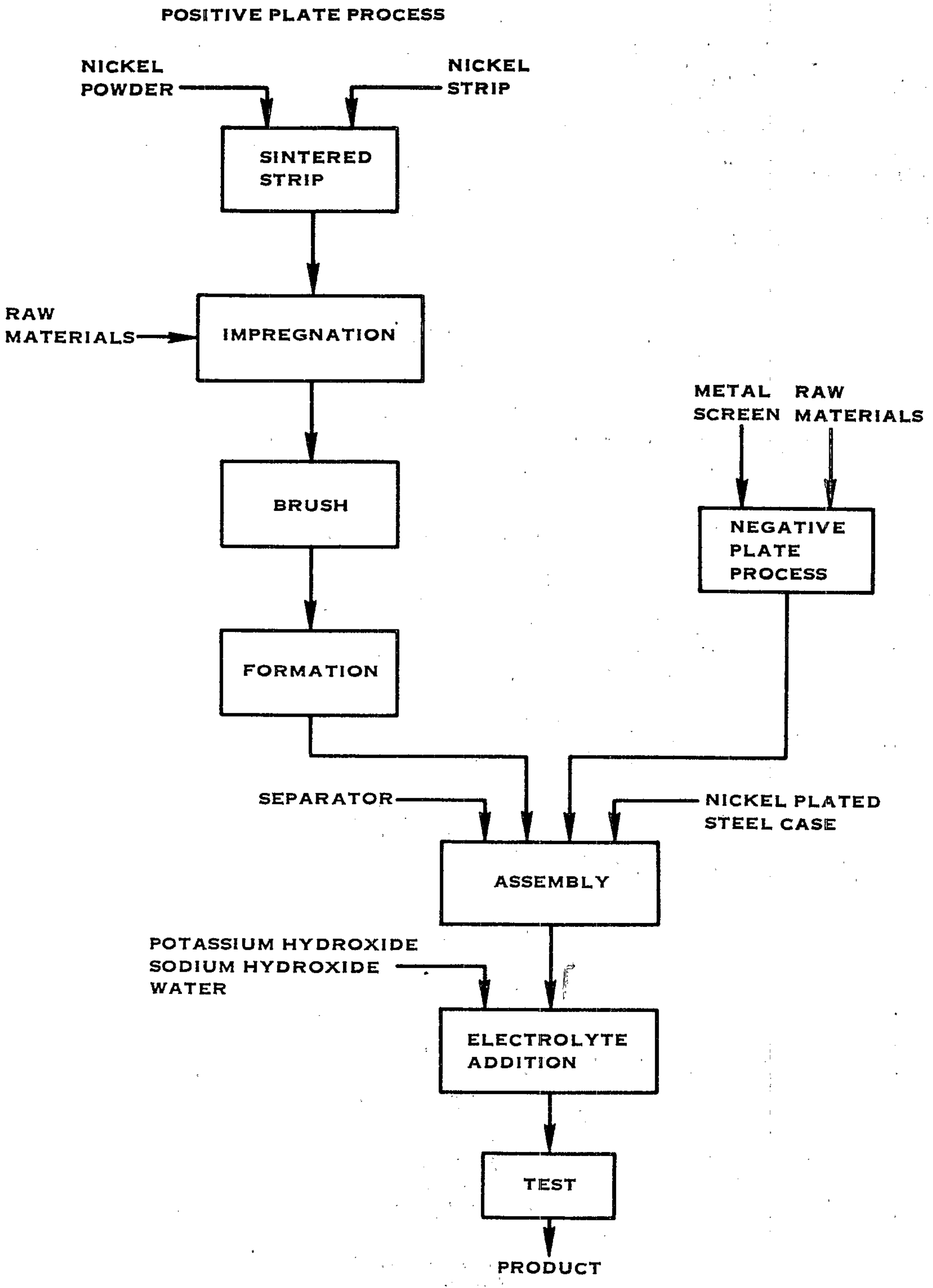


FIGURE III-13
MAJOR PRODUCTION OPERATIONS IN NICKEL-CADMIUM BATTERY MANUFACTURE

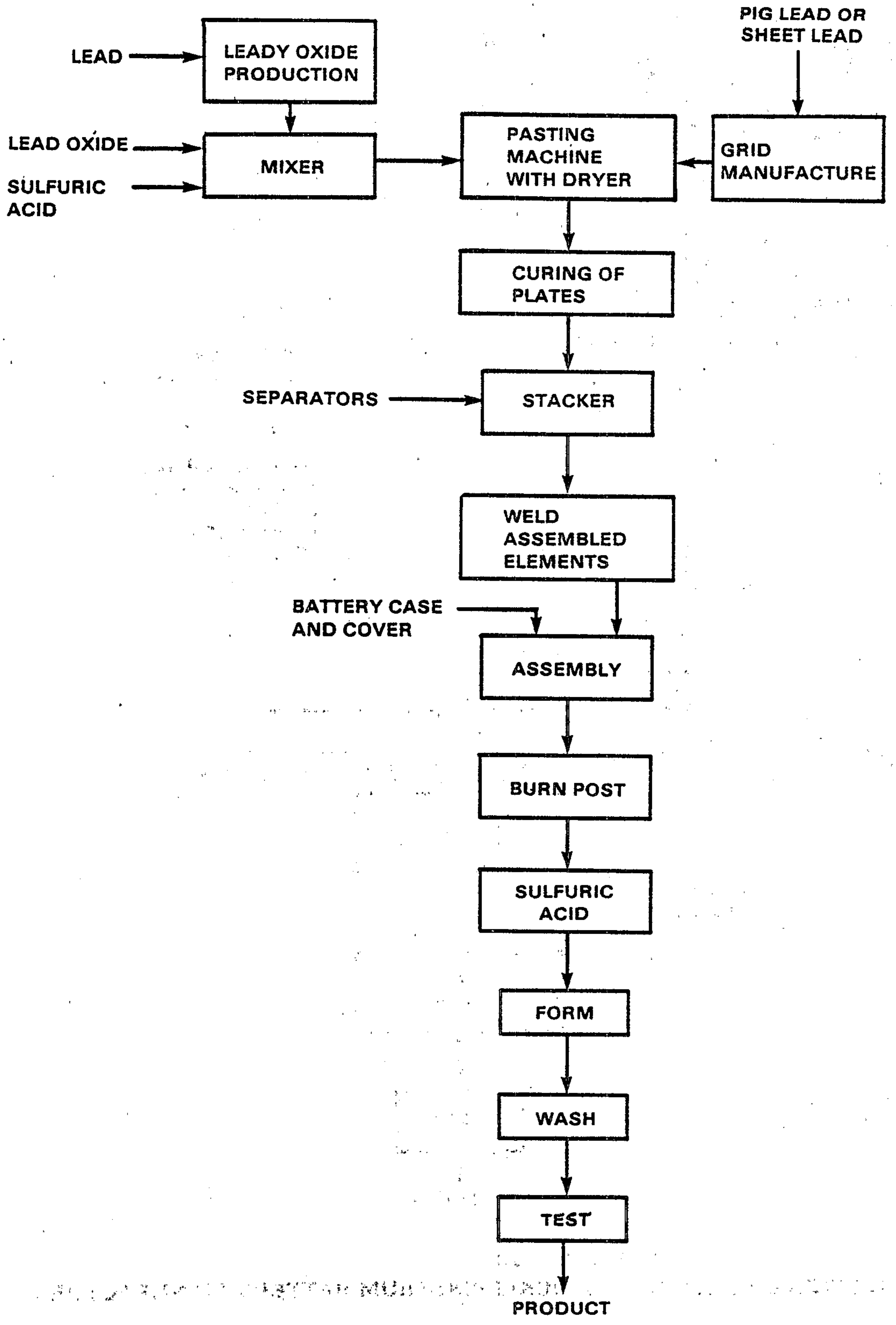


FIGURE III-14
SIMPLIFIED DIAGRAM OF MAJOR PRODUCTION OPERATIONS IN LEAD ACID BATTERY MANUFACTURE

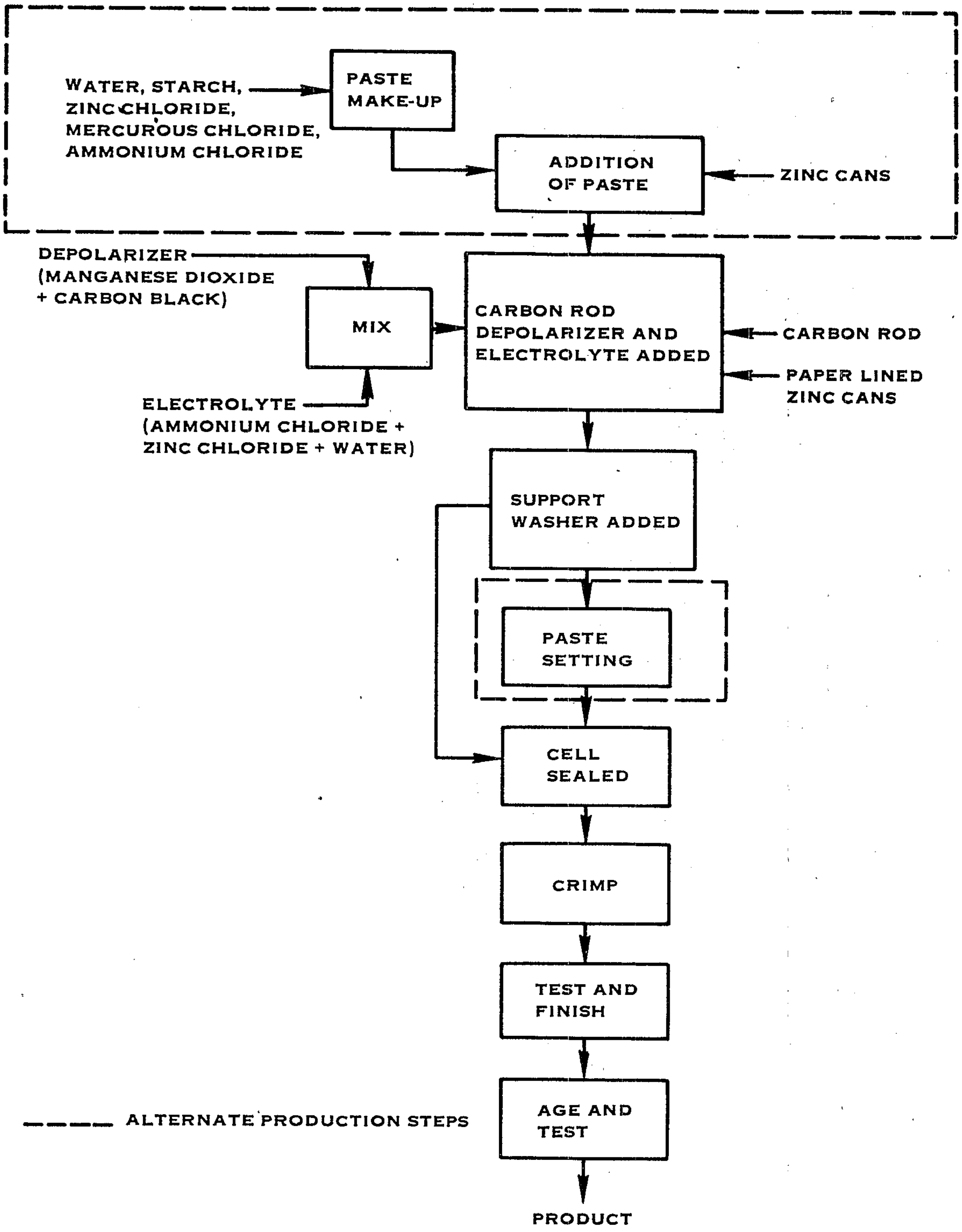


FIGURE III-15
MAJOR PRODUCTION OPERATIONS IN LECLANCHE BATTERY MANUFACTURE

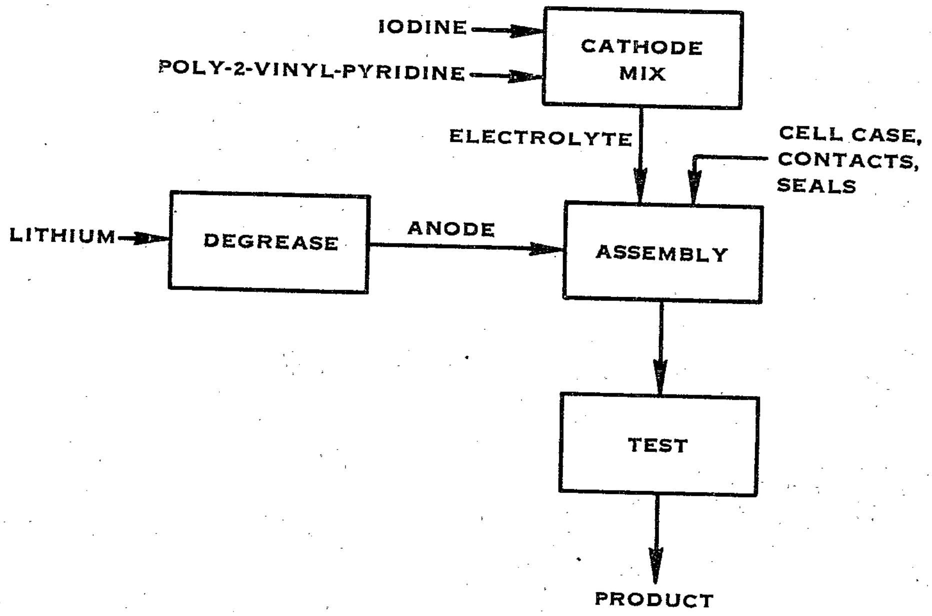


FIGURE III-16
MAJOR PRODUCTION OPERATIONS IN
LITHIUM-IODINE BATTERY MANUFACTURE

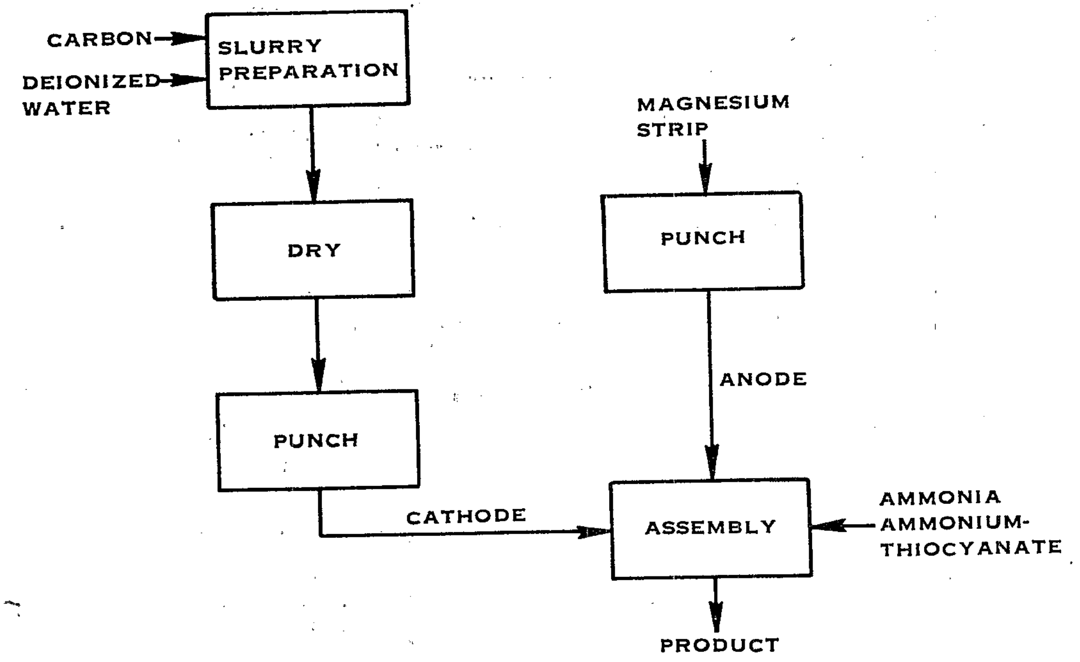


FIGURE III-17
MAJOR PRODUCTION OPERATIONS IN AMMONIA-ACTIVATED MAGNESIUM RESERVE CELL MANUFACTURE

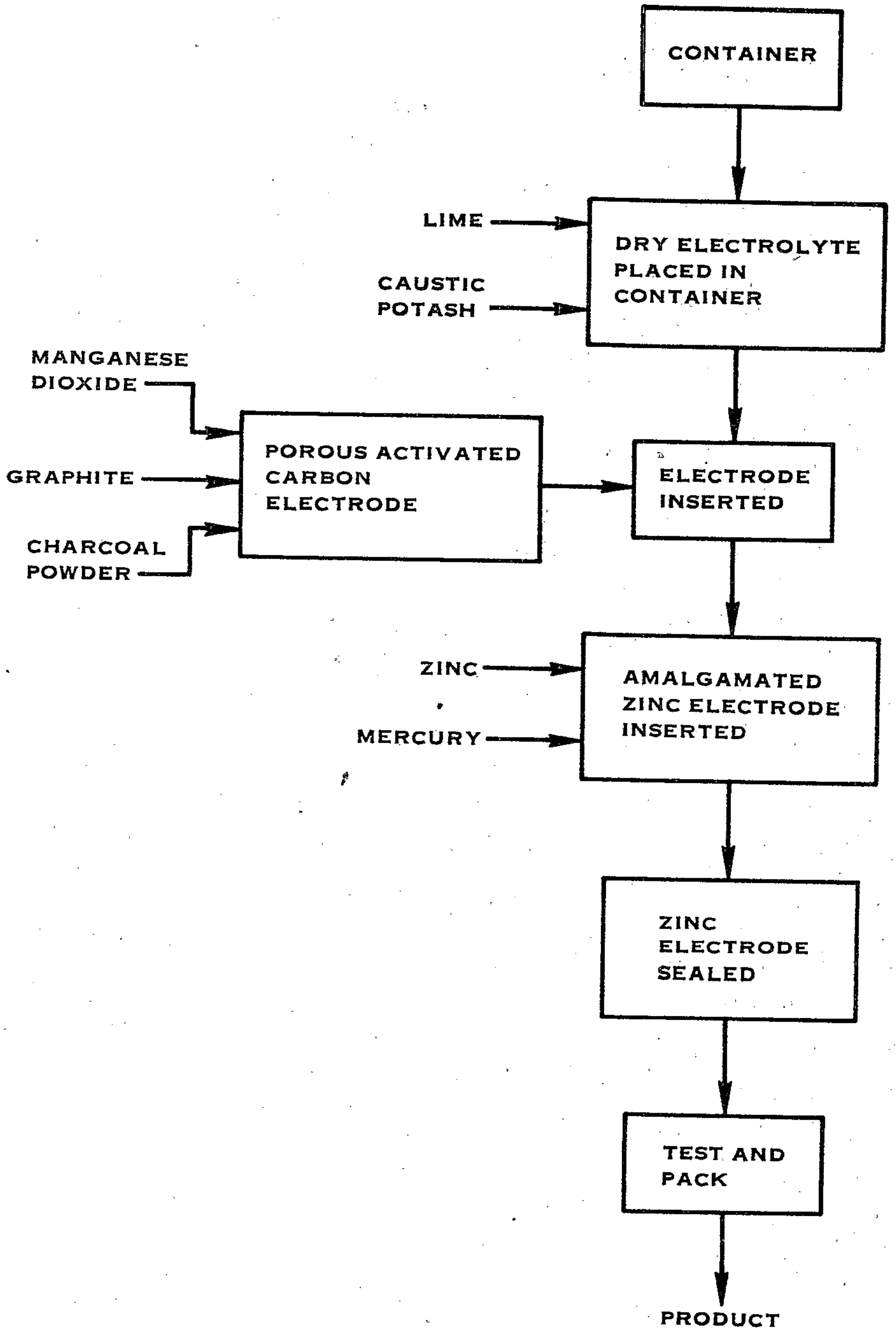


FIGURE III-18
MAJOR PRODUCTION OPERATIONS IN WATER ACTIVATED CARBON-ZINC-AIR CELL MANUFACTURE

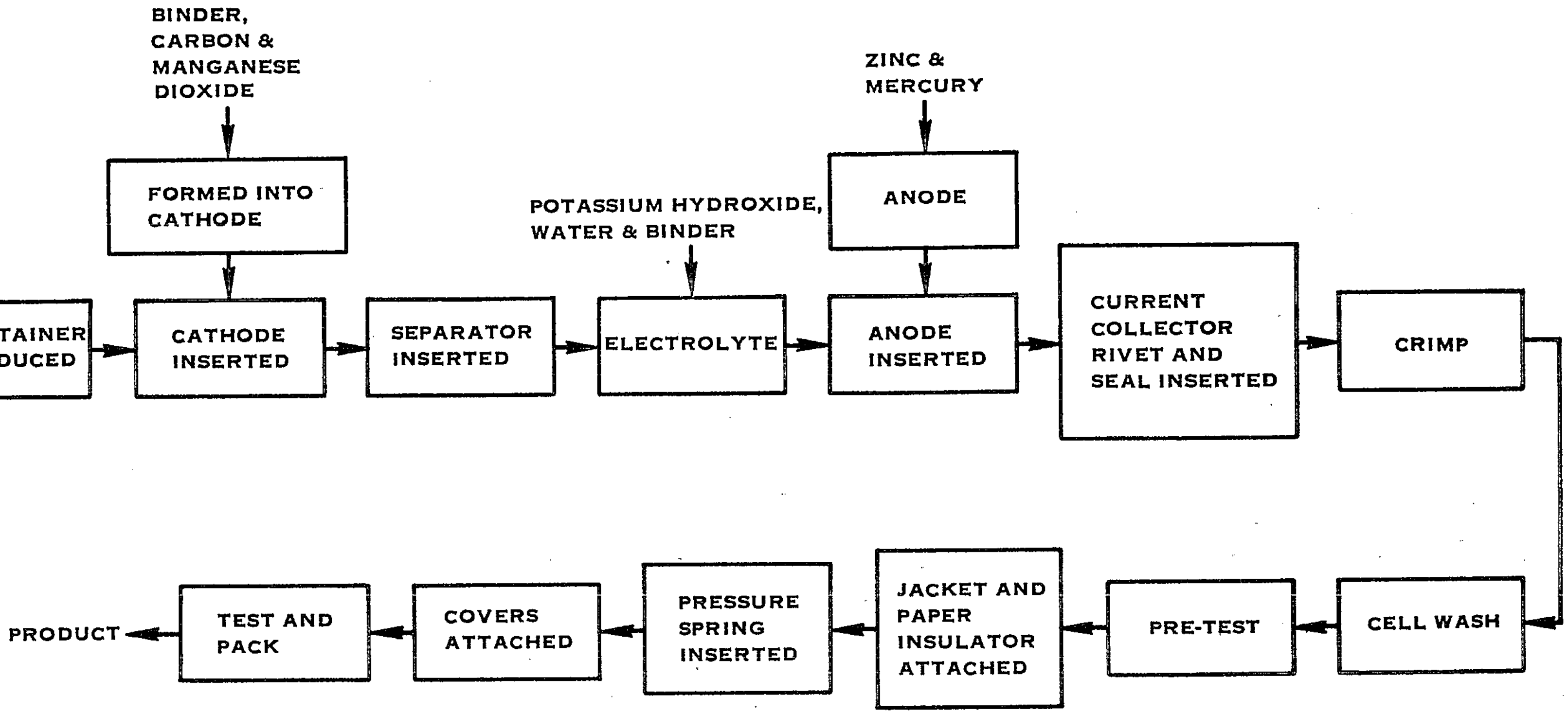


FIGURE III-19
MAJOR PRODUCTION OPERATIONS IN ALKALINE-MANGANESE DIOXIDE BATTERY MANUFACTURE

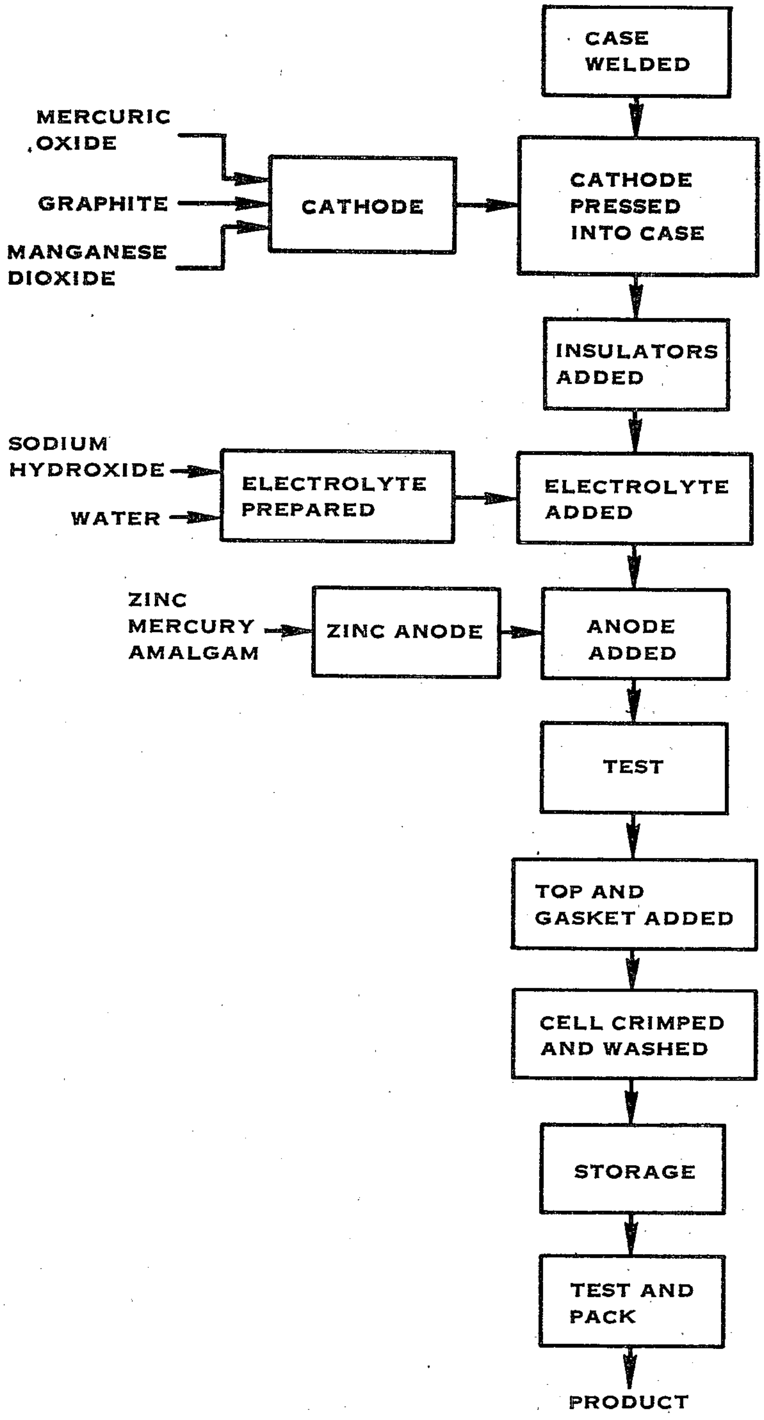
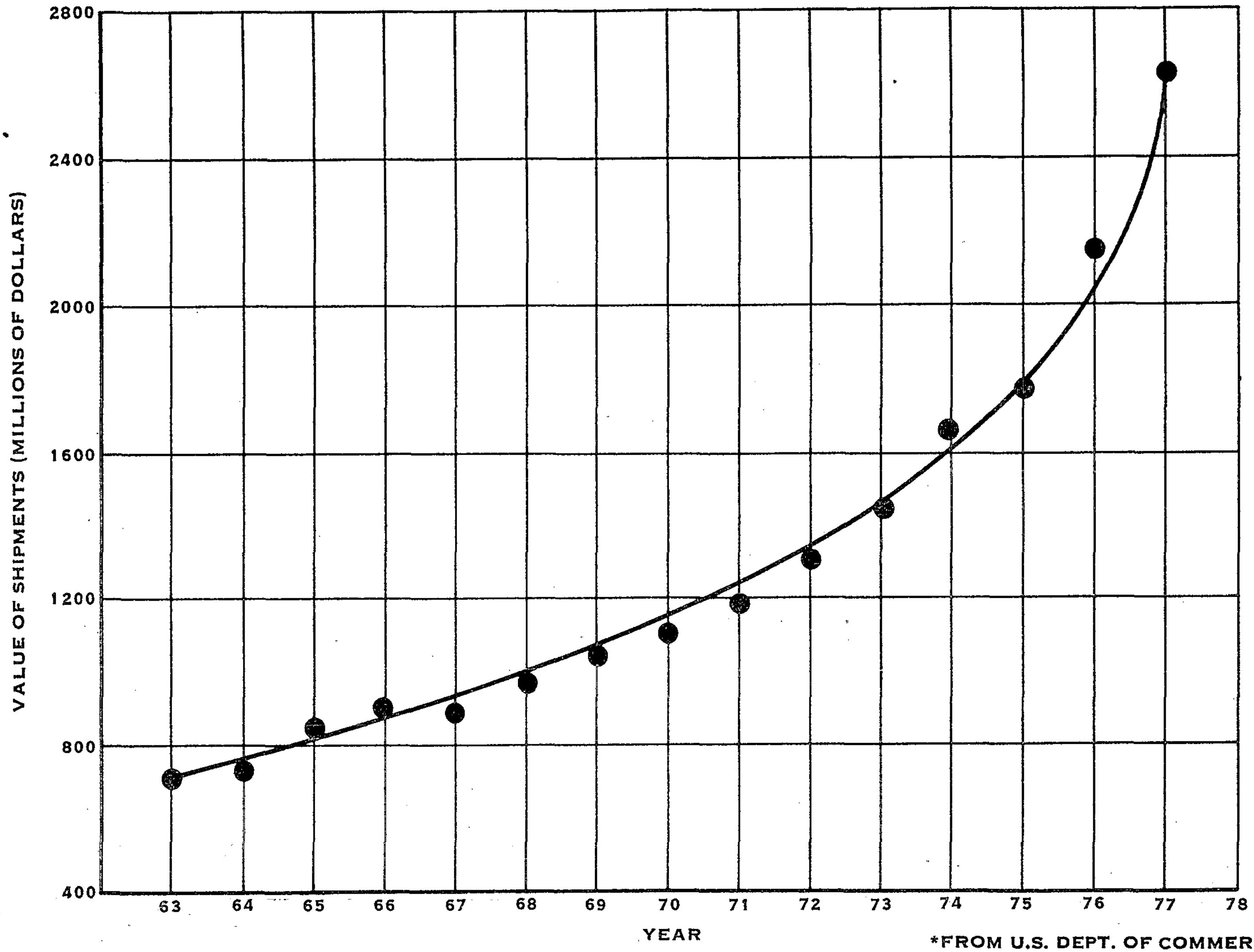


FIGURE III-20
SIMPLIFIED DIAGRAM OF MAJOR OPERATIONS IN MERCURY-ZINC (RUBEN) BATTERY MANUFACTURE



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

FIGURE III-21
VALUE OF BATTERY PRODUCT SHIPMENTS 1963–1977*

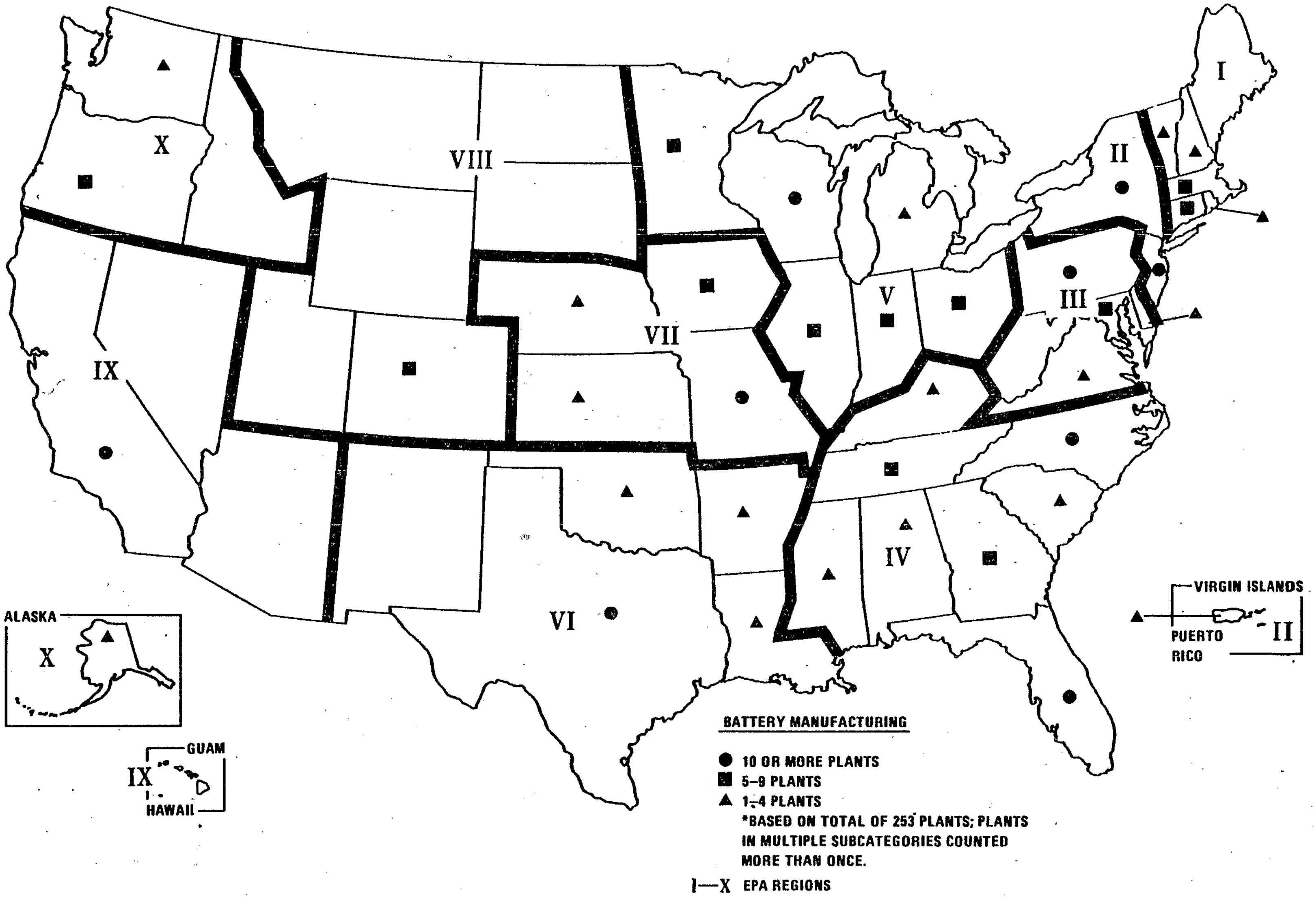


FIGURE III – 22
GEOGRAPHICAL REGIONAL DISTRIBUTION OF BATTERY MANUFACTURING PLANTS

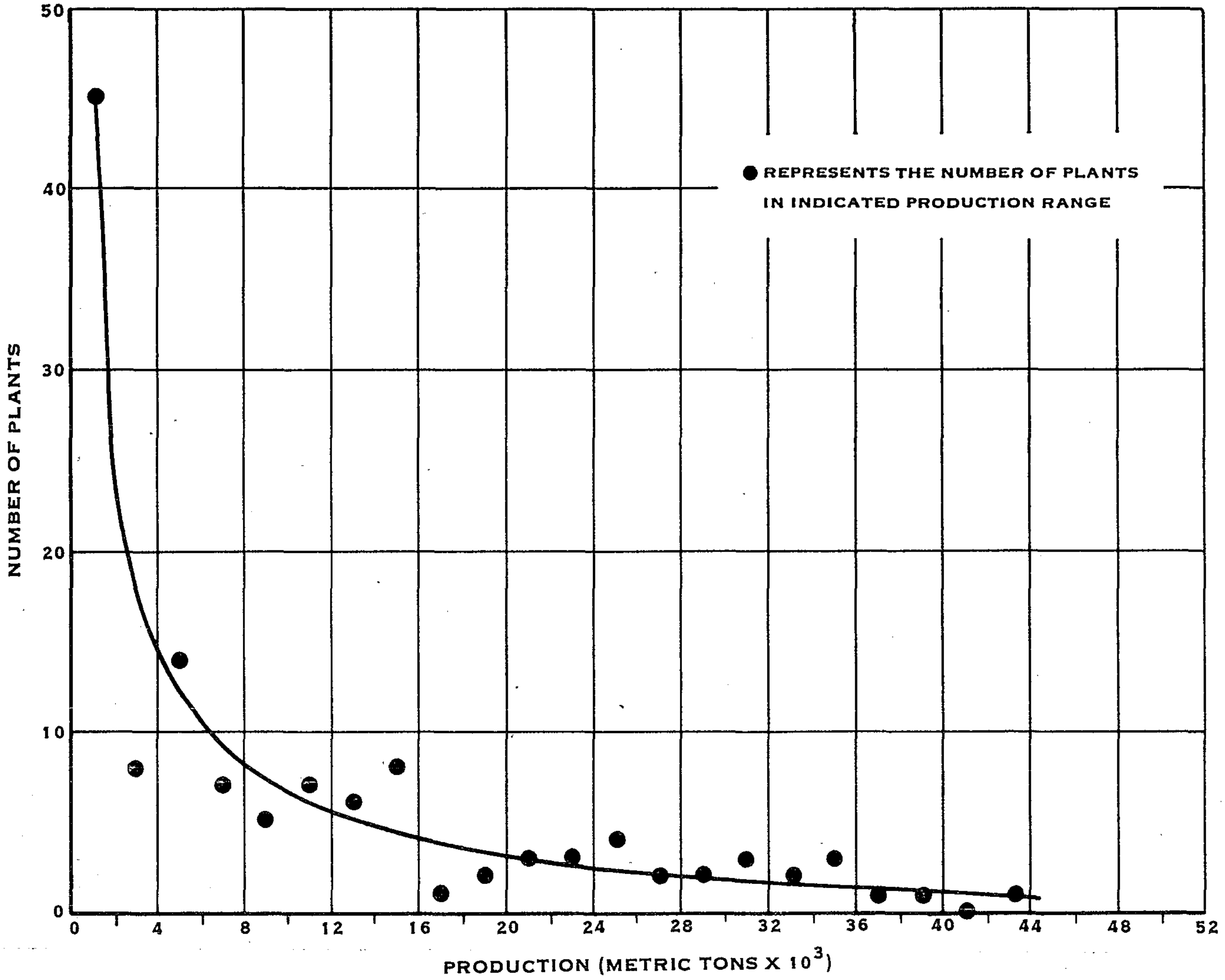


FIGURE III-23
DISTRIBUTION OF LEAD SUBCATEGORY PRODUCTION RATES

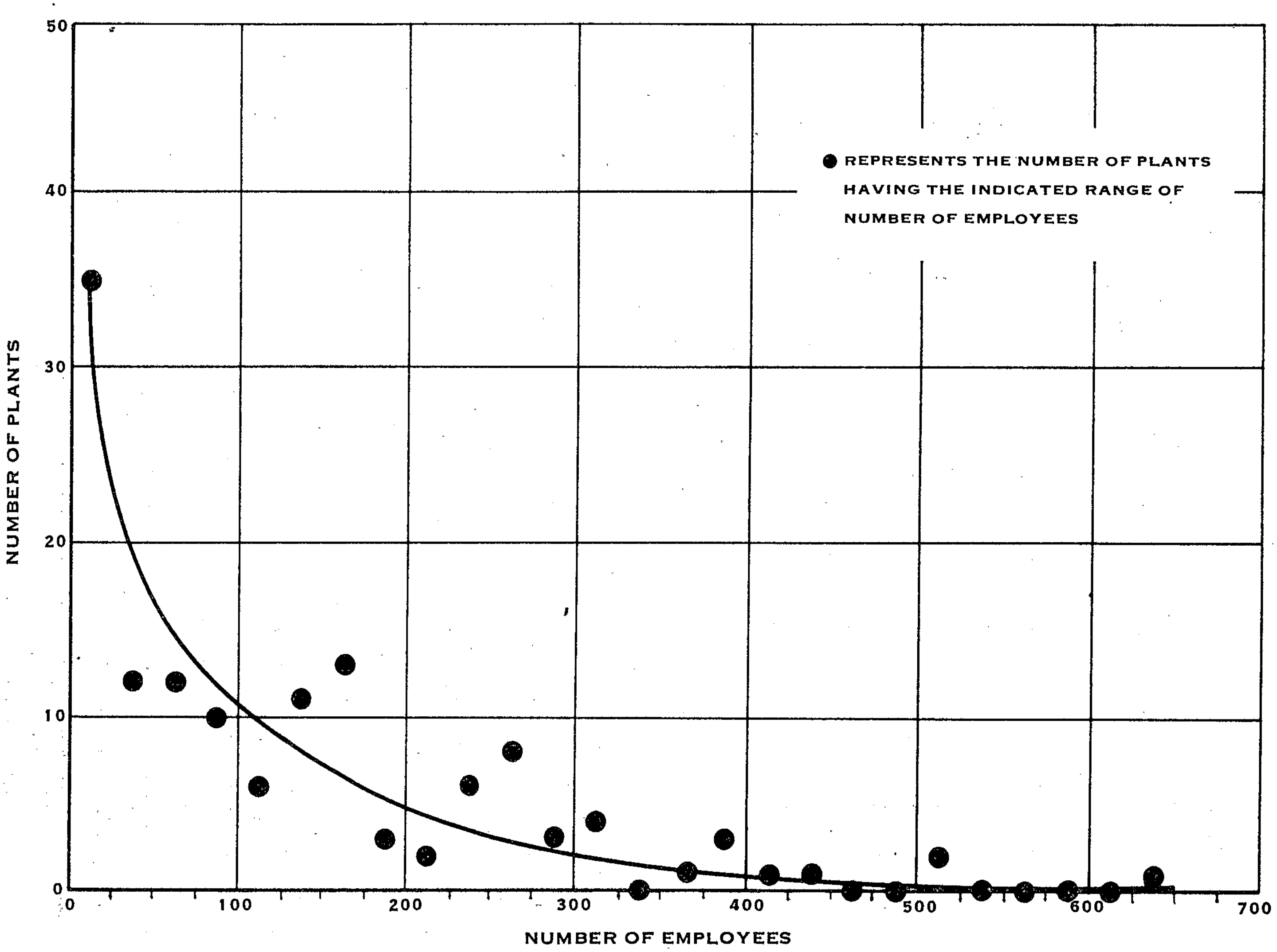


FIGURE III-24
DISTRIBUTION OF EMPLOYMENT AT LEAD SUBCATEGORY MANUFACTURING PLANTS

SECTION IV
INDUSTRY SUBCATEGORIZATION

Subcategorization should take into account pertinent industry characteristics, manufacturing process variations, water use, wastewater characteristics, and other factors which are important in determining a specific grouping of industry segments 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 and 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 battery components and raw materials and may include operations not specific to battery manufacture. A number of 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 factors is discussed in the ensuing paragraphs, followed by a description of the process leading to selection of the anode subcategorization.

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)
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 as 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 at a single site 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 over 200 subcategories, battery type was found to be unacceptable as the 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 sources of wastewater generation, 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 that result in significant differences in wastewater generation are reflected in the manufacturing process elements for which specific discharge allowances were developed within each subcategory.

Water Use - Water use alone is not a comprehensive enough factor upon which to subcategorize because water use is related to the various manufacturing processes used and product quality needed. While water use is a key element in the limitations and standards established, it is not directly related to the source or the type and quantity of the waste. For example, water is used to rinse electrodes and to rinse batteries. The amounts of water used for these processes might be similar, but the quantity of pollutants generated is significantly different.

Water Pollution Control Technology, Treatment Costs, and Effluent Discharge Destination - 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. The treatment technology does not affect the raw wastewater characteristics. Likewise, the effluent discharge destination does not affect the raw wastewater characteristics.

Solid Waste Generation and Disposal - 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 wastes resulting from the manufacture of batteries includes process wastes (scrap and spent solutions) and sludges resulting from wastewater treatment. The solid waste characteristics (high metals content), as well as wastewater characteristics, are a function of the specific battery type and manufacturing process. However, not all solid wastes can be related to wastewater generation and be used for developing effluent limitations and standards. Also, solid waste disposal techniques may be identical for a wide variety of solid wastes but cannot be related to pollutant generation. These factors alone do not provide a sufficient base for subcategorization.

Size of Plant - The size of a plant is not an appropriate subcategorization factor since the wastewater characteristics per unit of production are essentially the same for different size plants that have similar processing sequences. However, the size of a plant is related to its production capacity. 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 because the wastewater characteristics of plants are also dependent on the type of processes performed.

Age of Plant - 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 subcategorization because it does not take into consideration the significant parameters which affect the raw wastewater characteristics. In addition, a subcategorization based on age would have to distinguish between the age of the plant and the age of all equipment used in the plant which is highly variable. Plants in this industry modernize and replace equipment relatively frequently, and changes of subcategories would often result. Subcategorization using this factor is therefore infeasible.

Number of Employees - The number of employees in a plant does not directly provide a basis for subcategorization since the number of employees does not reflect the production processes used, the production rates, or water use rates. Plants producing batteries varied widely in terms of number of production employees. The volume and characteristics of process wastewater was found to not 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 obtain reliable energy estimates specifically for production and waste treatment. When available, estimates are likely to include other energy requirements such as lighting, air conditioning, and heating 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 primary source of wastewater generation in the battery manufacturing category, and therefore, not acceptable as an overall subcategorization 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 do not necessarily have similar processes and, consequently 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. For example, 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 plants that have access to plentiful water supplies and thus, constitute a basis for effluent control rather than for subcategorization.

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

After reviewing and evaluating data for this category, the initial battery type subcategorization was replaced by the anode material, electrolyte approach. This development is discussed below in detail.

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. This approach 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 plants. 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 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.

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 200. 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 plants 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 plants 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 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 plants 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 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 manageable 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 plants
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 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. All subcategories except for lead are discussed specifically in Volume I of the <u>Development Document for Effluent Limitations Guidelines and Standards for the Battery Manufacturing Point Source Category</u>.

These subcategories preserve most of the recognized battery types within a single subcategory and greatly reduce the 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 under this approach 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 subcategorization. In most cases where process operations are common to multiple battery types, the processes 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 plants are similar.

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, or ancillary) there are numerous manufacturing processes or production functions. These processes or functions 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 107). 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; these are 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 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. At the element level, flows and pollutant characteristics can be related to production. Elements are combined or can be combined in various ways at specific plants at the subcategory level. Wastewater treatment can be related to this level which is considered the level of regulation. The detailed information which contributed 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

For lead batteries the determination was made that one subcategory would be appropriate. The subcategory however, needed to be divided into separate elements or process operations to account for various wastewater flow differences and process mixes at different plants. Also, lead used was selected as the most appropriate production normalizing parameter. Specific elements within the lead subcategory are summarized in Table IV-1 (page 105). Discussion of the process elements and selection of a production normalizing parameter is discussed below.

Lead Subcategory

All lead batteries 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
- Leady Oxide Production
  - Purchased oxide
  - On site production
    - Ball Mill process
    - Barton process
- Grid Manufacture
  - Grid casting
  - Mold Release Formulation
  - Direct chill casting
  - Lead rolling
- Plate Curing
  - With steam
  - Humidity temperature controls
  - Stacked
- Plate Formation (Charging)

Closed Formation (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)

Open Formation

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

- Plate Soak

- 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. Other operations which are not specifically associated with manufacturing operations contribute to wastewater generation: floor wash, wet air pollution control, battery repair, laboratories, truck wash, and personal hygiene related activities. 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 the manufacture of batteries produced was chosen as the production normalizing parameter for all process elements for which discharge allowances are provided in this subcategory except truck wash. The production normalizing parameter for truck wash is the weight of lead in batteries moved over the highway in trucks, because this relates more closely with what is actually washed. Total battery weight, electrode surface area, total electrode weights, electrical capacity of the battery, 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 consistent basis for effluent limitations and standards. 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 lead operations. Significant difficulty is encountered in defining the surface area, however, and data were not always 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 area was not chosen as the production normalizing parameter for these operations.

Electrical capacity of the battery should, in theory, correspond closely to 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 is often the major source of process wastewater. It was not, however, for use in this study because electrical capacity data were not obtained.

Becuase 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. Although the number of employees would be a suitable basis for limiting discharges from employee showers and handwashes, battery weight was chosen instead to achieve uniformity with other ancillary wastewater sources and to minimize the number of production normalizing parameters to be applied.

OPERATIONS COVERED UNDER OTHER CATEGORIES

Some lead subcategory 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 are identified in Table IV-2 (page 106) and are discussed in reference to the lead subcategory below. Specific operations are discussed in Section V.

Plants producing batteries within the lead subcategory perform a number of processes which may be performed in other industrial categories. Most plants 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. For the purposes of this battery manufacturing regulation, lead casting (die cast or direct chill) performed at battery manufacturing plants is regulated under the battery manufacturing category. Lead rolling is included under the battery manufacturing category but is not specifically regulated because there are no dischargers. Guidance is provided for those battery manufacturing plants which may perform this function and need to discharge wastewater. The production of lead oxide at lead battery plants is a unique operation yielding a "leady oxide" distinct from lead oxide produced in inorganic chemical production. It is included under the battery manufacturing category for the purpose of effluent limitations and standards.

Several lead battery plants report the recovery of lead from scrap batteries. These processes - battery cracking and secondary lead smelting are included under the nonferrous metals manufacturing point source category. Some lead anode battery plants also produce rubber or plastic battery cases on-site which are not regulated under the battery manufacturing point source category.

TABLE IV-1

LEAD SUBCATEGORY ELEMENTS AND PRODUCTION NORMALIZING PARAMETER (PNP)[1]

Anodes and Cathodes	Leady Oxide Production
	Grid Manufacture
	Grid Casting
	Mold Release Formulation
	Direct Chill Casting
	Lead Rolling
	Paste Preparation and Application
	Curing
	Closed Formation (in case)
	Single Fill
	Double Fill
	Fill and Dump
	Open Formation (out of case)
	Wet
	Dehydrated
	Plate Soaking
Ancillary	Battery Wash
	Detergent
	Water Only
	Floor Wash
	Wet Air Pollution Control
	Battery Repair
	Laboratory
	Truck Wash[2]
Personal Hygiene	Hand Wash
	Respirator Wash
	Laundry

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[1] Production Normalizing Parameter (PNP) is the total weight of lead used.

[2] PNP is weight of lead in trucked batteries.

TABLE IV-2

OPERATIONS AT BATTERY PLANTS INCLUDED IN OTHER INDUSTRIAL CATEGORIES

(Partial Listing)

- Plastic and Rubber Case Manufacture
- Retorting, Smelting and Alloying Metals
- Inorganic Chemical Production (Not Specific to Battery Manufacturing)

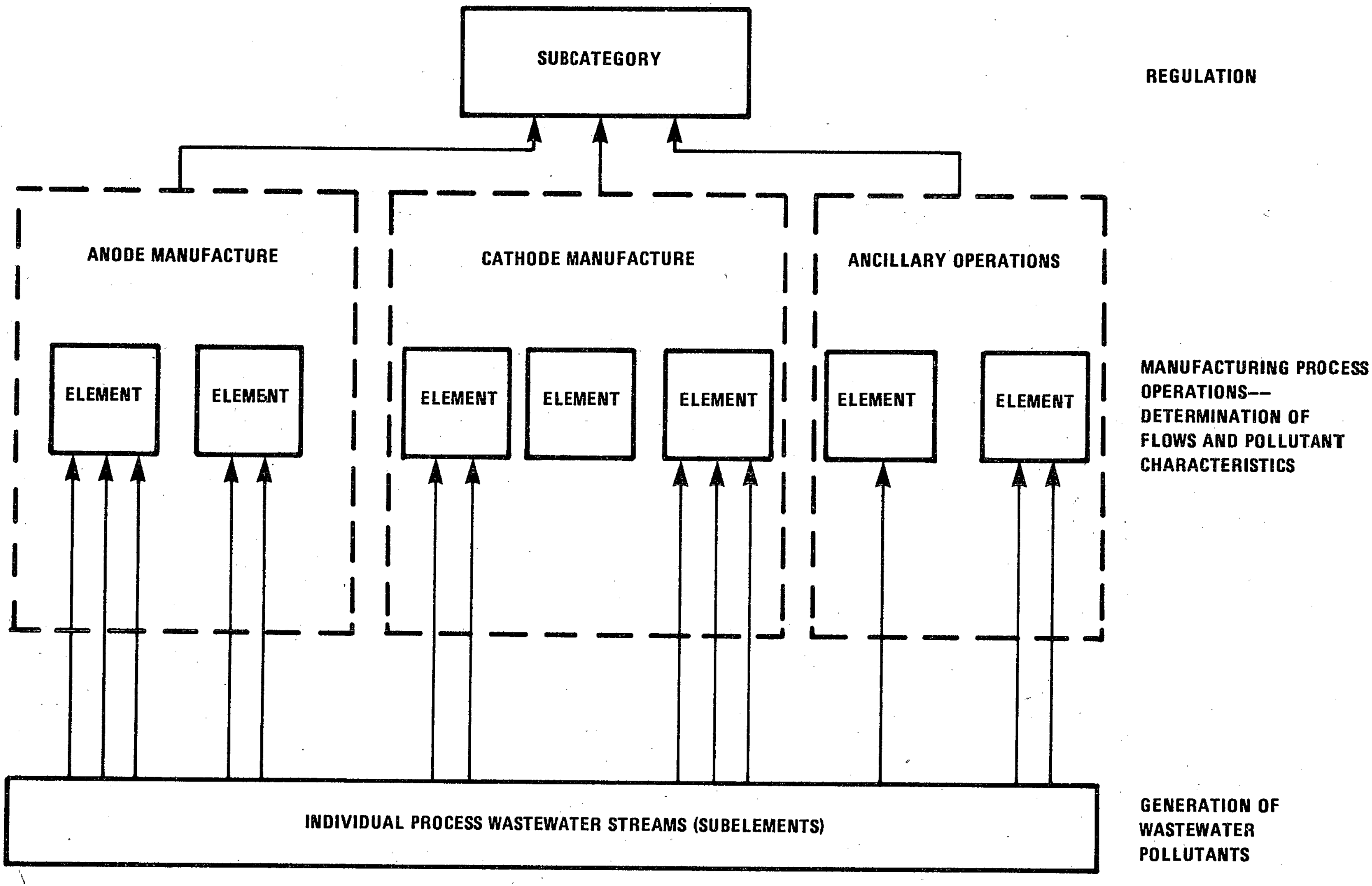


FIGURE IV–1 SUMMARY OF CATEGORY ANALYSIS

SECTION V

WATER USE AND WASTEWATER CHARACTERIZATION

This section describes the collection, analysis, and characterization of data that form the basis for effluent limitations and standards for the lead subcategory, and presents the results of these efforts. Data were collected from a number of sources including published literature, previous studies of battery manufacturing, data collection portfolios (dcp) mailed to all known battery manufacturers, industry surveys mailed to lead battery manufacturers after proposal, and on-site data collection and sampling at selected facilities. Data analysis began with an investigation of the manufacturing processes practiced, the raw materials used, the process water used and the wastewater generated in the entire battery category. This analysis was the basis for subcategorization of battery manufacturing which resulted in a separate lead subcategory, and also was the basis for selection of the lead subcategory production normalizing parameter (pnp) already discussed in detail in Section IV. Further analysis included collecting wastewater samples and characterizing wastewater streams within the lead subcategory.

DATA COLLECTION AND ANALYSIS

The sources of data used in this study have been discussed in detail in Section III. For the lead subcategory, data collection and analysis were conducted in two phases, before and after proposal. Prior to proposal data collection served to provide a subcategorization scheme as well as characterize manufacturing processes, water use, and treatment. After proposal, extensive data collection and analysis was performed for the lead subcategory in order to address issues received in comments from the lead battery industry.

Published literature and previous studies of the battery manufacturing category provided a basis for initial data collection efforts and general background for the evaluation of data from specific plants. The dcp sent to all known battery manufacturing companies provided the most complete and detailed description of the category which could be obtained. Dcp were used to develop category and lead subcategory data summaries and were the primary basis for the selection of sites for pre-proposal on-site sampling and data collection. Data from these plant visits were used to characterize raw and treated wastewater streams within the lead subcategory and provide an in-depth evaluation of the impact of product and process variations on wastewater characteristics and treatability.

Prior to proposal, data analysis proceeded concurrently with data collection and provided guidance for the initial data collection effort. Initially, a review and evaluation of the available information from published literature and previous studies was used as the basis for developing the dcp format which structured the preliminary data base for category analysis. This effort included the definition of preliminary subcategories within the battery manufacturing category. These subcategories were expected to differ significantly in manufacturing processes and wastewater discharge characteristics. Consequently on-site data collection and wastewater sampling were performed for each subcategory. Specific sites for sampling were selected on the basis of data obtained from completed dcp. For each subcategory, screening samples were collected and analyzed for all priority pollutants and other selected parameters. The results of these screening analyses, plus the dcp data, were evaluated to select significant pollutant parameters within each subcategory for verification sampling and analysis.

After proposal, additional data were collected to augment existing data in response to a number of comments received from lead battery manufacturers and their trade associations. A survey was developed and distributed to lead battery manufacturers to assess wastewater treatment system operating characteristics, solid waste disposal, and process water use practices. Based on industry comments and survey responses, sites were selected for data collection and additional sample analysis. Data from these site visits were used to further characterize raw and treated process wastewater streams to assess wastewater characteristics and treatability. Also, grid manufacture operations proposed for regulation under the metal molding and casting category were transferred to the lead subcategory. Visit data were used to augment existing data concerning water use and air pollution control practices in the grid manufacturing process operations.

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, effluent quality, and presence or absence of priority pollutants in wastewaters from battery manufacturers. Because many lead battery manufacturers operate on-site casting facilities, a dcp addressing casting operations for the metal molding and casting (foundry) category was included with the battery manufacturing dcp. After collection of the data, the determination was made that process wastewater discharges from casting were initially to be evaluated as part of the foundry category.

For data gathering purposes, a list of companies known to manufacture batteries was compiled from Dun and Bradstreet Inc. SIC code listings, battery industry trade association membership lists (Battery Council International (BCI) and Independent Battery Manufacturers Association (IBMA) for lead batteries), listings in the Thomas Register, and lists of battery manufacturers compiled during previous EPA studies. These sources included battery distributors, wholesalers, corporate headquarters and individual plants. The lists were screened to identify corporate headquarters for companies manufacturing batteries and to eliminate distributors and wholesalers. As a result, a total of 226 dcp were mailed to each corporate headquarters, and a separate response was requested for each battery manufacturing plant operated by the corporation. Following dcp distribution, responses were received confirming battery manufacture by 133 companies operating at 235 manufacturing sites. Of these, 184 lead battery manufacturing sites were identified. Because of the dynamic nature of battery manufacturing these numbers vary since some new sites have been built, some sites have consolidated operations, and some have closed. Since proposal, information was received which revealed that 19 lead battery sites have closed, while 2 new sites have been built.

Specific information requested in the dcp was determined on the basis of an analysis of data available from published literature and previous EPA studies of this category, and consideration of data requirements for the promulgation of effluent limitations and standards. This analysis indicated that wastewater volumes and characteristics varied significantly among different battery types according to the chemical reactants and electrolyte used, and that raw materials constituted potential sources of significant pollutants. In addition, batteries of a given type were commonly produced in a variety of sizes, shapes, and electrical capacities. Available data also indicated that processes could vary significantly in wastewater discharge characteristics.

As a result of these considerations, the dcp was developed so that specific battery types manufactured, manufacturing processes practiced, and the raw materials used for each type could be identified. Production information was requested in terms of both total annual production (lbs/yr) and production rate (lbs/hr). The dcp requested data for the year 1976, the last full year for which production information was expected to be available. Some plants provided information for 1977 and 1978 rather than 1976 as requested in the dcp. All data received were used to characterize the industry. Water discharge information was requested in terms of gallons per hour. The dcp also requested a complete description of the manufacturing process for each battery type, including flow diagrams designating points and flow rates of water use and discharge, and type and quantity of raw materials used. Chemical characteristics of each process wastewater stream were also requested.

Basic information requested included the name and address of the plant and corporate headquarters, and the names and telephone numbers of contacts for further information. Additionally, the dcp included a request for a description of wastewater treatment practices, water source and use, wastewater discharge destination, and type of discharge regulations to which each plant was subject. Since the wastewaters at each plant had not been analyzed for the priority pollutants, the dcp asked whether each priority pollutant was known or believed to be present in, or absent from, process wastewater from the plant.

Of the 184 confirmed lead battery manufacturing sites, all but 10 returned either a completed dcp or a letter with relevant 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 six of the 10 plants which did not provide a written response had less than five employees and with the other four comprised a negligible fraction of the industry.

The quality of the responses obtained varied significantly. Although most plants could provide most of the information requested a few indicated that available information was limited to the plant name and location, product, and number of employees. These plants were generally small and usually reported that they discharged no process wastewater. Also, process descriptions varied considerably. Plants were asked to describe all process operations, not just those that generated process wastewater. As a result over 50 percent of the lead subcategory plants submitting dcp indicated that certain process operations did not generate wastewater. In some dcp specific process flow rates conflicted with water use and discharge rates reported elsewhere in the dcp. Specific process flow information provided in the dcp was sufficient to characterize flow rates for most process elements for the lead 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 plants. Raw waste chemical analysis was almost universally absent from the dcp and had to be developed almost entirely from sampling at visited plants and data from previous EPA studies.

Upon receipt, each dcp was reviewed to determine plant products, manufacturing processes, wastewater treatment and control practices, and effluent quality (if available). Subsequently, selected data contained in each portfolio were entered into a computer data base to provide identification of plants with specific characteristics (e.g. specific products, process operations, or waste treatment processes), and to retrieve basic data for these plants. The dcp data base provided quantitative flow and production data for each plant. This information was used to calculate production normalized flow values as well as wastewater flow rates for each process element in the lead subcategory. The data base was also used to identify and evaluate wastewater treatment technologies and in-process control techniques used.

Industry Survey

After proposal, the Agency determined that additional data were required in order to address a number of issues in comments received from lead battery manufacturers and trade associations. An industry survey was developed to assess wastewater treatment system operating characteristics including effluent quality; solid waste disposal; process water use practices; and personal hygiene and cleaning practices required at the plant.

The Battery Council International (BCI) played a major role in the development of the industry survey. BCI distributed the survey to their membership and to the Independent Battery Manufacturing Association (IBMA). Completed forms were sent to the EPA at the request of BCI. EPA received survey responses from 65 plants. Two of the survey responses indicated that their plants were closed and did not provide any new data.

The data provided in the industry surveys, along with the dcp data base were carefully considered in formulating the promulgated regulation. Industry survey data were particularly useful in evaluating personal hygiene and cleaning practices at lead battery plants.

Plant Visits and Sampling (Pre-Proposal)

Seventeen lead subcategory plants were visited prior to proposal. At each plant, information was obtained about the manufacturing processes, raw materials, process wastewater sources (if any), and wastewater treatment and control practices. Wastewater samples were collected at 5 lead subcategory plants.

Prior to proposal, the collection of data on priority, conventional and nonconventional pollutants in waste streams generated by this category was accomplished using a two-phase sampling program. The first phase, screening, was designed to provide samples of influent water, raw wastewater and treated effluent from a representative plant in each subcategory. Samples from the screening phase were analyzed and the results evaluated to determine the presence of pollutants in a waste stream and their potential environmental significance. Those pollutants found to be potentially significant in a subcategory were selected for further study under the second, or verification, phase of the program. This screening-verification approach allowed both investigation of a large number of pollutants and in-depth characterization of individual process wastewater streams without incurring prohibitive costs.

Plant Visits and Sampling (Post-Proposal)

Engineering site visits were made to seventeen lead subcategory sites after proposal. Sites were selected in order to obtain the data necessary to accurately address the issues raised during the comment period. During the site visits the Agency collected information, where available, about the quality and flow rate of raw and treated water, including treatment effectiveness data from plants where monitoring was conducted. Additionally, the Agency collected samples for chemical analysis for verification at five of the sites visited. These samples were collected to characterize pollutant loadings in raw waste streams and to determine the effectiveness of end-of-pipe treatment. Analytical data collected on the post-proposal sampling visits have been combined with the data collected prior to proposal and are included in the data base presented in this section.

Sampling and Analysis Procedures

Sampling procedures were applied for all sampling programs including screening and verification sampling and post-proposal sampling. For the screening effort, plants identified as being representative of the subcategory in terms of manufacturing processes, raw materials, products, and wastewater generation were selected for sampling.

Screening samples were obtained to characterize the total process wastewater before and after treatment. All screening was performed according to EPA protocol as documented in Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, April 1977. Only the combined raw waste stream and total process effluent were sampled. At plants that had no single combined raw waste or treated effluent, samples were taken from discrete waste sources and a flow-proportioned composite was used to represent the total waste stream for screening.

Asbestos data were collected from one lead plant as part of a separate screening effort using self-sampling kits supplied to the selected plant. The sampling protocol for asbestos was developed after the initial screening efforts had been completed. Consequently, asbestos data on plant influent, raw wastewater, and effluent for each subcategory was not necessarily collected from the same plants involved in the initial screening.

Plants were selected for verification sampling on the basis of the screening results. Those plants within the subcategory that demonstrated effective pollutant reductions were specifically identified for sampling in order to evaluate wastewater treatment and control practices. Plants were selected for post-proposal sampling to obtain data to adequately address several issues concerning process wastewater flows and effective treatment practices that arose during the comment period.

Initially, each potential sampling site was 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 (a) specific process wastewater samples needed to characterize process raw waste streams and wastewater treatment performance and (b) any additional data required. Each plant was usually visited for one day to determine specific sampling locations and collect additional information. In some cases, it was determined during the preliminary visit that existing wastewater plumbing at the plant would not permit meaningful characterization of battery manufacturing process wastewater. In these cases, plans for sampling the site were discontinued. For plants chosen for sampling, a detailed sampling plan was developed on the basis of the preliminary plant visit identifying sampling locations, flow measurement techniques, sampling schedules, and additional data to be collected during the sampling visit.

Sample points were selected at each plant to characterize a process wastewater from each distinct process operation, the total process waste stream, and the effluent from wastewater treatment. Multiple wastewater streams from a single process operation or unit, such as the individual stages of a series rinse, were not sampled separately but combined as a flow-proportioned composite sample. In some cases, wastewater flow patterns at specific plants did not allow separate sampling of certain process waste streams, and only samples of combined wastewaters from two or more process operations were taken. 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 before any treatment, such as settling in sumps, dilution, or mixing that would change its characteristics. When samples could not be taken before treatment, sampling conditions were carefully documented and considered in the evaluation of the sampling results.

As a result of the pre-proposal and post-proposal sampling visits to lead battery plants, over 100 raw waste samples were obtained which characterize wastewater sources from 21 process elements. In addition, samples were obtained from plant water supplies. Samples were also taken for analysis which either characterized wastewater streams from sources other than battery manufacturing that were combined for treatment with battery manufacturing wastes or characterized wastewater at intermediate points in treatment systems that used several operations.

Samples for verification were usually collected at each site on three successive days. Except if precluded by production or wastewater discharge patterns, 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 at a rate of one per hour. For batch operations composites were prepared by combining grab samples from each batch. Wastewater flow rates, pH, and temperature were measured at each sampling point hourly for continuous operations. For batch operations, these parameters were measured at the time the sample was taken. At the end of each sampling day, composite samples were divided into aliquots and taken for analysis of organic priority pollutants, metals, TSS, and oil and grease. Separate grab samples were taken for analysis of volatile organic compounds and for total phenols because these parameters would not remain stable during compositing. Composite samples were kept on ice at 4°C during handling and shipment. Analysis for metals was by plasma arc spectrograph for screening and by atomic absorption for verification. Metals analyses were done by both methods for post-proposal sampling. Atomic absorption was used for analysis of antimony and arsenic. Analysis for organic priority pollutants was performed by gas chromatograph-mass spectrometer for screening. For verification analysis, gas chromatograph-mass spectrometer (GCMS) and gas chromatograph were used for organic priority pollutant analysis as required by EPA protocol. No organic analyses were performed for sampling done after proposal. All sample analyses were performed in accordance with the EPA protocol listed in Table V-1 (page 164).

The sampling data provided wastewater chemical characteristics as well as flow information for the manufacturing process elements within the subcategory. Long-term flow and production values from the dcp data base or average flow and production values obtained during sampling were used as a basis for calculating a production normalized flow for each process element. A single value for each plant that most accurately represented existing plant operations was used to avoid excessively weighting visited plants (usually three days of values) in statistical treatment of the data.

Mean and median statistical methods were used to characterize each process element production normalized flow and wastewater characteristics. The mean value is the average of a set of values, and the median of a set of values is the value below which half of the values in the set lie. For the additional process wastewater streams considered after proposal, a flow weighted average was calculated using production and other parameters from a number of plants. Production normalized flows for the lead subcategory are described in detail later in this section.

All data were used to determine total process element and subcategory wastewater discharge flows. For plants that did not supply process wastewater discharge flows, but did provide production data, the mean of the individual production normalized flow values was used.

Screening Analysis Results

The results of screening analysis for the lead subcategory are presented in Table V-2 (page 170). Pollutants reported in the dcp as known or believed to be present in process wastewater from plants in the subcategory are also indicated on this table. In the table, ND indicates that the pollutant was not detected and NA indicates that the pollutant was not analyzed. For organic pollutants other than pesticides, the symbol * is used to indicate detection at less than or equal to 0.01 mg/l, the quantifiable limit of detection. For pesticides (pollutants 89-105), the symbol ** indicates detection less than or equal to the 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. The analytical methods used for screening analysis could not separate concentrations of certain pollutant parameter pairs, specifically pollutants numbered 72 and 76, 78 and 81, and 74 and 75. These pollutant pairs will have the same reported concentrations. Alkyl epoxides, and xylenes were not analyzed in any samples because established analytical procedures and standards were not available at the time of analysis. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) was not analyzed because of the hazard in laboratory analysis associated with handling TCDD standards. In the screening analysis tables dioxin is listed as not detected because analysis was not done for this pollutant. Analysis of asbestos was accomplished using microscopy. Results of asbestos analysis are reported as fibers being present or absent from a sample. The symbol + is used to indicate the presence of chrysotile fibers.

Selection Of Verification Parameters

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

1. Occurrence of the pollutant in process wastewater from the subcategory may be anticipated because the pollutant is present in, or used as, a raw material or process chemical. Also the dcp priority pollutant segment indicated that the pollutant was known or believed to be present in process wastewaters.
2. The pollutant was found to be present in the process wastewater at quantifiable limits based on the results of 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 detected concentrations were considered significant following an analysis of the ambient water quality criteria concentrations and an evaluation of concentrations detected in blank, plant 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 is presented in the following paragraphs.

For the lead subcategory, the following 30 pollutant parameters were selected for further analysis:

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
67	butyl benzyl phthalate
68	di-n-butyl phthalate
69	di-n-octyl phthalate
78	anthracene
81	phenanthrene
84	pyrene
114	antimony
115	arsenic
124	nickel
126	silver
128	zinc
	aluminum
	iron
	manganese
	phenols (4AAP)
	strontium
	oil and grease
	TSS
	pH

Eighteen organic priority pollutants were detected in screening at concentrations at or below the quantification level. These pollutants, acenaphthene, benzene, 2,4,6,trichlorophenol, 2-chlorophenol, 1,3-dichlorobenzene, 2,4-dichlorophenol, ethylbenzene, fluoranthene, dichlorobromomethane, chlorodibromomethane, 1,2-benzanthracene, 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 to be present in process wastewater by at least one plant in the subcategory but were not detected in screening analysis. On the basis of 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 to be present in one dcp, but 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, though detected only at the quantifiable limit, because they were reported to be present in process wastewater in dcp 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. 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 at the limit of detection. Because beryllium was not known to be related to battery manufacture, it was not selected for verification. Antimony, although detected at the limit of detection, was selected for verification 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 lead 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. After proposal, aluminum and manganese were also detected and included in verification analysis. 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.

Presentation of Analytical Results. Pre-proposal and post-proposal parameter analytical results are discussed and tabulated by process element in the discussion which follows this section. Pollutant concentration (mg/l) tables are shown for each sampled process. In the tables 0.00 indicates no detection for all organic pollutants. For organic pollutants, the symbol * is used to indicate detection at less than or equal to 0.01 mg/l, the quantifiable limit of detection. For the metals, total suspended solids, and oil and grease, 0.000 indicates the pollutant was not detected above the quantifiable limit. When samples were flow proportionally combined for a process, the values shown are calculated, and 0.0000 indicates that the pollutant was detected in at least one sample of the combined process wastewater stream. For chemical analysis, the *'s are calculated as positive values which cannot be quantified, but for statistical analysis are counted as zeroes.

LEAD SUBCATEGORY

Batteries manufactured in this subcategory use lead anodes, lead peroxide cathodes, and acid electrolytes. Lead subcategory cells and batteries, however, differ 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 similar to dehydrated batteries and are produced from lead electrodeposited on steel. 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.

Lead subcategory battery production reported in dcp totaled 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. Less than 1 percent of the subcategory total production is for lead reserve batteries. Reported annual production of batteries at individual plants 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 dehydrated 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.

Process water use and wastewater discharge vary widely among lead subcategory plants because of differences in control of water use, wastewater management practices, and 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 also were observed to differ widely, leading to significant variability in effluent quality. Most plants in the subcategory discharge process wastewater to POTW, and many provide little or no pretreatment.

Manufacturing Process and Water Use

The manufacture of lead batteries is illustrated in the generalized process flow diagram presented in Figure V-1 (page 240). 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 production; (3) paste preparation and application 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) formation or charging (including plate soaking) which further binds the paste to the grid and renders the plate electrochemically active; (8) final assembly; (9) battery testing and repair if needed; (10) battery washing; and (11) final shipment. Each of these process steps may be accomplished in a variety of ways and they may be combined in different overall process sequences depending on intended use and desired characteristics of the batteries being produced. Process steps (1) through (7) are anode and cathode operations while assembly, battery testing and repair, and battery washing are ancillary operations. Additional ancillary operations involved in the manufacture of lead batteries include floor and truck washing, laboratory testing, and personal hygiene activities. Personal hygiene activities include mandatory employee handwashing, respirator washing, and laundering of employee work uniforms. Each process step and ancillary operation identified above is a process element in the lead subcategory. These process elements, and their various combinations form the basis for analysis of lead subcategory process wastewater generation as shown in Figure V-2 (page 241). A general discussion summarizing water use data collected for the lead subcategory process elements is provided below. Following this discussion, the process elements are discussed individually. Each process element discussion includes a process description and a summary of the process element water usage.

Water Use Data - Wastewater flow data for the lead subcategory process elements were collected from the dcp, site visits, and written responses to EPA requests for data. These flow data were normalized with production data in order to compare flows from different sized battery plants. The production normalizing parameter is generally the total weight of lead used for all processes. Lead use data were originally provided in the dcp, however, after proposal, the Agency obtained more recent (1982) lead use data from 41 plants. Production normalized flow values for these 41 plants were calculated using the more recent (1982) lead use data. Mean and median normalized discharge flows from all dcp, site visit, and written response data for the wastewater production processes are summarized in Table V-3. This table also shows the number of plants which reported flow data for each process.

Table V-3 contains a number of wastewater sources for which limited flow data is available. In the case of mold release formulation, laboratory, hand wash, respirator wash, and laundry, a flow weighted average calculation procedure was used to calculate the mean normalized flow. This procedure varied somewhat for the different operations due to differences in available flow data; specific calculation procedures are provided in each of the process element discussions. The calculation of the average normalized flows for hand washing, respirator washing, and laundry was determined with the aid of lead battery manufacturers survey data regarding personal hygiene activities. Personal hygiene activity data are summarized in Table V-4.

Normalized flow data for the major wastewater producing manufacturing process elements are summarized in Figure V-3. This figure shows the distribution of production normalized flows for each process operation at those plants which produce a wastewater discharge for the process operation. Plants which report no process wastewater from the process are not represented on the curves. The insert on the figure presents for each process the median of the non-zero flows, the median of all flows 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 (for plants supplying specific process flow data).

As the regression lines on Figure V-3 indicate the dispersion in the flow data (indicated by the slopes of the lines) showed no significant differences among the different process operations shown on the figure. The slope for leady oxide production was slightly less than the slope of other process element lines. This difference is judged to be insignificant. 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 suggested 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 plants without any major process change.

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 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, silver and tellurium may be added to grids.

Impurities found in lead grids include copper, silver, zinc, bismuth, and iron. Newly developed grid structures discussed in the literature use ABS plastic grids coated with lead or polystyrene interwoven with lead strands for the negative plate, but no plant reported commercial manufacture of these grid types.

Two different operations are used to manufacture grids in the lead subcategory: (1) grid casting (a form of die casting) of lead and (2) perforating by punching or piercing and expanding of lead. The latter can be preceeded by the actual manufacture of the sheet which includes direct chill casting and lead rolling processes. Based on dcp data, grid casting is performed at 130 lead subcategory sites and was performed at 14 of the 17 sites visited after proposal. Grid fabrication by punching or piercing and expanding is known to be practiced by at least 10 plants and the practice is growing. Melting furnaces or pots are used to produce molten lead for both grid casting and direct chill casting methods. These melting furnaces generate fumes which are removed by wet air pollution control devices at some sites. Wet air pollution control is discussed later in this section. Both of the grid manufacturing methods are discussed below.

Grid Casting - Grid casting is performed by cooling molten lead in metal molds to produce individual grids. The molten lead is cooled by passing noncontact cooling water through the mold. This non-process water is recycled through cooling towers at some sites, discharged direct 14 to the sanitary sewer at other sites, or discharged to wastewater treatment. If the water is recycled through cooling towers, non-process cooling tower blowdown water is discharged to the sewer or to wastewater treatment.

The use of molds in grid casting requires the use of a mold release compound which prevents the molten lead from adhering to the mold upon cooling. Mold release compounds are either cork or silica based with either kerosene or silicon carrier fluids. These compounds can either be purchased or formulated on-site. Twenty-nine sites owned by two companies reported formulating their mold release compound on-site. Process wastewater is generated from on-site mold release formulation by cleaning equipment after mixing batches of the release material. Flow information for mold release formulation was obtained after proposal from both of the companies which report this activity. At one company approximately 50 gallons per day of water are used at each site for equipment cleanup. At the other company, 75 gallons of water are used per day at each site.

The average production normalized flow (0.006 l/kg) for mold release formulation was calculated as follows:

- For each company, the company mold release formulation flow was multiplied by the number of company sites to determine the total company mold release formulation flow.
- The total company mold release formulation flow was then divided by the total company production to determine a production normalized flow for the company.
- The two production normalized company flows were then averaged.

Perforating - In this process, grids are manufactured by perforating sheet lead by various methods. The sheet lead can be continuously punched and coiled or cut into individual grids. This method does not generate wastewater and lead scrap from the punching is reclaimed. The sheet metal can also be pierced and expanded into grids with no wastewater discharge, although a neglibible amount of aqueous emulsion is used for lubrication. This method can be preceded by manufacture of the lead sheet by direct chill casting and lead rolling.

In direct chill casting, molten lead flows by gravity through a die. This die is sprayed with contact cooling water which causes the lead to solidify into a continuous strip of about two inches thick. The continuous strip is then reduced to the desired thickness (0.05 in.) in a rolling mill. Following rolling, the lead strip is aged for one to two weeks to increase tensile strength prior to grid fabrication.

Water usage data for direct chill casting and lead rolling were collected on a post-proposal sampling visit to one site reported to be active in these processes. At this site, direct chill casting contact cooling water drains to a catch tank and is continuously recirculated. The catch tank is drained to treatment about once every four months. The average production normalized flow of 0.0002 l/kg was calculated for direct chill casting as follows:

- Catch tank dimensions at the sampled site were measured.
- The annual discharge flow from direct chill casting was then calculated assuming three batch dumps per year.
- The annual discharge flow was divided by the site's annual production to determine the average normalized flow.

In lead rolling, an aqueous emulsion of 0.5 percent oil is used to lubricate the rolling mills. This emulsion is continuously recirculated and subsequently contract hauled once per week to treatment and disposal off-site. Based on flow data from the sampled site, 0.006 l/kg of spent solution are contract hauled.

Leady Oxide Production. 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 the exothermic oxidation reaction 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 air flow and by non-contact cooling of the ball mill, or bearings.

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 use on electrodes. Recycled lead recovered by remelting scrap is normally used in casting grids, straps, and terminals.

Water use and wastewater generation associated with leady oxide production is dependent on the process (Barton or ball mill) used. The Barton process uses only non-process water for cooling screw conveyors and other mechanical parts. Shell cooling water is the primary source of process wastewater from ball mills.

Five of the 17 sites visited after proposal used the Barton process. None of these sites generated process wastewater. In the ball mill process, a number of cooling configurations have been observed in this subcategory. At some sites, noncontact cooling water was used to cool bearings. This cooling configuration does not generate a process wastewater stream since the cooling water does not contact lead dust or other contaminants. Other sites use water to cool the shell of the ball mill. Cooling in this manner may produce a process wastewater stream due to entrainment and dissolution of lead dust when the ball mill is not shrouded properly. Four of the 17 sites visited after proposal operate ball mills. One of these sites cools only bearings generating no process wastewater. Three of the sites use shell cooling water with widely varying cooling configurations. One site uses once-through shell cooling. One has two ball mills with two different cooling configurations: in one ball mill, once through shell cooling water is used while at the other ball mill the shell cooling water is recirculated with minimal wastewater generation. The third site uses a completely closed recirculating cooling configuration with annual sump cleaning.

Twenty-nine of the 41 plants submitting data for this process reported zero discharge of wastewater. Nine of the 12 plants reporting discharge flows from leady oxide production are from shell cooling. Two of 12 are discharges associated with wet scrubbers. Wet scrubber discharges from leady oxide production are included in the wet air pollution control process element which is discussed later in this section. The remaining flow is an unidentified process wastewater discharge. The average production normalized flow is 0.37 l/kg and median is 0.00 l/kg.

<u>Paste Preparation and Application</u>. Lead oxides are pasted on the grid to produce electrode plates with a porous, high area, reactive surface. The pores provide maximum contact of 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, or red lead with 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 lignosulfonic acid. Addition of expanders amounting to an aggregate 1 or 2 percent of the paste can increase the negative plate effective area by several hundred percent.

Hardeners have been added to pastes (e.g., glycerine and carbolic acid), but prevailing practice is to control this property 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 is added to the paste to produce proper consistency and increase paste adhesion. During acid addition, considerable heat is evolved. Temperature must be controlled to produce a paste with the proper cementing action. Paste is applied to the grids by hand or machine.

The major source of wastewater from paste preparation and application is equipment and area cleanup. Equipment and area cleanup is a required procedure because different paste formulations may be used on any one pasting line, and the equipment must be periodically cleaned. Fifty-seven of the 100 plants submitting flow data on this process report zero discharge of wastewater from paste preparation and application. Zero discharge is accomplished by settling and recycling paste area water for equipment washdown. The settled paste can also be reclaimed. The average production normalized flow for this process is 0.49 l/kg and the median is 0.00 l/kg.

Sixteen of the 17 sites visited after proposal perform paste formulation and application operations. Seven of these sites do not discharge wastewater from equipment and area washdown. Another site was planning to install a complete recirculation washdown water system by December 1983.

Some plants use wet scrubbers to control dust generated during paste mixing. These wet scrubbers are discussed later in this section under the wet air pollution control process element.

Curing. The drying and curing operations must be carefully controlled to provide electrodes with the porosity and mechanical strength required for adequate battery performance and service life. The purpose of curing 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 them (air curing), placing them in humidity controlled rooms or ovens (humidity curing) for several days, or directly applying steam in a controlled environment (steam curing) to convert free lead particles in the plates to lead oxide. The free lead is reduced from 24-30 percent to the desired level (5 percent or less) during curing. Proper conditions of temperature and humidity allow 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. Steam curing increases the rate of curing by providing controlled humidity at higher temperatures.

Multiple curing techniques are used by a number of sites in the subcategory. For instance, at some sites plates are first cured in humidity controlled rooms or ovens. The curing process is then completed in covered stacks. Other sites first steam cure plates and then finish the curing process in humidity controlled rooms. At some sites only positive plates are steam or humidity cured while at other sites both positive and negative plates are steam or humidity cured. Process wastewater discharge from curing was reported by ten of the 97 plants that supplied flow data. The average production normalized flow for this process is 0.03 l/kg and the median is 0.00 l/kg. Discharge of wastewater from curing is associated with humidity curing and steam curing. Wastewater discharge from humidity curing results from condensation in humidity controlled rooms and once-through spray water from humidity curing ovens. Wastewater discharge from steam curing is associated with steam condensation.

Although a few sites discharge wastewater from steam or humidity curing, other sites have demonstrated that these operations can be performed without the discharge of process wastewater. Eight of the 17 sites visited after proposal do not discharge wastewater from positive or negative plate curing. Of these, six use humidity controlled rooms for both types of plates; one uses steam curing for both types of plates and one uses ambient curing, humidity controlled rooms, or steam curing depending on the battery and type of plate.

Semi-Assembly (Stacking, Grouping, Separator Addition) Following curing, 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.

Separators prevent short circuiting between the anode and cathode yet permit electrolyte conduction between the electrodes. Separators also may serve to provide physical support to the positive plate. The configuration and the material of separators differ according to the specific properties desired. Materials used for separators in lead acid storage batteries include paper, plastic, rubber, and fiberglass.

Water use in the semi-assembly operation is limited to non-contact cooling water associated with welding of elements and groups. No process wastewater is generated or discharged from the semi-assembly operation.

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 usually proceeds in two steps. The acid is first cut to an intermediate concentration (about 45 percent acid) which may be used in paste preparation. 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.

For some battery applications, sodium silicate is added to the electrolyte prior to addition to the battery. The resulting thixotropic 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.

Acid cutting generates heat and generally requires the use of non-contact cooling water. Process wastewater is not generally produced. Wet scrubbers are reported to be in use at some sites to control acid fumes but are used as dry mist eliminators and do not generate process wastewater. Since water is consumed ~~in~~ "cutting" acid, some sites use this process as a sink for process wastewater contaminated with acid and lead, thereby reducing or eliminating the volume requiring treatment and discharge.

The addition of electrolyte to batteries for formation and for shipment is frequently a source of wastewater discharge in the form of acid spillage. 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 plants, batteries are filled by immersion in tanks of acid. Overfilling or filling by immersion results in significant contamination of the battery case with acid and necessitates rinsing prior to further handling or shipment, generating significant volumes of process wastewater. Acid spills also contaminate equipment in the formation area requiring periodic equipment washdown (formation area washdown). Wastewater flows from formation area washdown and battery rinsing are considered as flow values for the formation processes.

Formation (Charging) - Although lead peroxide is the active material of the finished positive plate, it is not a component of the paste applied to 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 within the battery case after assembly has been completed (closed formation) or in open tanks prior to battery assembly (open formation). Open formation is most often practiced in the manufacture of dehydrated plate batteries.

A number of charging techniques are used to form batteries in this subcategory. Charging techniques used for closed formation include (1) high rate formation, (2) low rate formation, (3) controlled charge rate formation, and (4) chilled acid formation. In high rate formation, batteries are formed rapidly in one day or less. When batteries are formed rapidly, heat generation is so rapid that the batteries must be cooled using fine sprays of water on the battery cases. This contact cooling water is a significant source of wastewater. Low rate formation is a charging technique in which batteries are charged at a constant rate which is low enough to adequately dissipate heat without using cooling water. Low rate charging requires formation periods of up to seven days. In controlled charging, the charging current is varied during the course of formation to maintain acceptable electrolyte temperatures. This eliminates the need for contact cooling water. Current variation is achieved manually or by the use of automatic timers or small computer devices. Controlled charging sometimes comprises charging slowly for a few hours initially, on the order of a few amps; then the rate is increased for most of the formation cycle, and then the rate is decreased again to finish charging. Other plants charge rapidly for nine to ten hours, then let the batteries cool for several hours and finish charging rapidly for approximately another nine hours. Overall controlled charging formation times have been observed to vary from nine hours to a total of 72 hours. Another charging technique observed in this subcategory is the use of chilled acid to reduce electrolyte temperatures in the initial stage of charging. Reduced electrolyte temperature in the initial stage of charging serves to reduce the overall charging time. The initial heat of reaction during the charge cycle is usually greater due to the presence of unreacted (uncured) lead oxide in the cured plate. Instead of charging slowly at first to dissipate heat, charging can proceed more rapidly immediately with the use of chilled acid.

Open formation charging periods have been observed to vary from approximately one to five days. Since batteries are formed in open tanks heat dissipation is not a problem in open formation.

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. As the electrolyte concentration increases, the rate of formation of positive plates decreases, but durability of the product improves. The rate of formation of negative plates increases by increasing acid concentration.

Single-Fill - 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. Thirty-one of the 43 sites reporting flow data for single fill formation achieve zero discharge. The average production normalized flow is 0.28 l/kg and the median is 0.00 l/kg. For sites that report a discharge, wastewater sources include area washdown, contact cooling water, and wet air pollution control scrubbers. Wet air pollution control scrubbers are used to remove fumes generated during charging and are discussed later in this section under the wet air pollution control process element. As discussed earlier, contact cooling water is a major source of wastewater at sites which use high rate charging.

Eight sites visited after proposal use single fill formation. Three of these sites use contact cooling water to dissipate heat generated during high rate charging. One of the three sites has two single fill operations. In one operation the cooling water is recycled through a water softening system while the other operation uses a once through cooling configuration which generates the majority of wastewater discharged to treatment at the site, about 200,000 gpd. The second site uses controlled charging with no wastewater generation for some batteries, and spray cooling for the remaining batteries. The third site uses spray cooling water to dissipate heat. The remaining five sites incorporate slow or controlled formation procedures which eliminate the need for cooling water.

Double-Fill - Double fill formation processes use a more dilute formation electrolyte than is used for single-fill formation. Formation of the battery is complete in about 24 hours. The formation electrolyte is removed for reuse, and more concentrated fresh electrolyte suitable for battery operation is added. Double fill-double charge batteries are given a boost charge prior to shipment.

Seven of the 35 sites reporting flow data for double fill formation achieve zero discharge. The average production normalized flow is 0.92 l/kg and the median is 0.44 l/kg. The sources of wastewater from double fill are essentially the same as for single fill: cooling water, area washdown, and wet air scrubber discharge. An additional source of wastewater associated with double fill operations is battery rinse water. Both filling and emptying battery cases may result in contamination of the case with acid, necessitating subsequent battery rinsing. The extent of this contamination depends on the filling and emptying techniques applied. The immersion filling method results in the most extensive battery case contamination and requires subsequent battery rinsing. Other filling methods have been observed which do not require battery rinsing.

The fraction of sites using immersion filling is much greater for double fill operations than for single fill. Based on post-proposal site visits three of four double fill sites use at least one filling procedure by immersion; only one of the eight sites visited used immersion filling for single fill operations. All sites using immersion filling were observed to rinse batteries. Conversely, very few double fill plants practice contact cooling; none were observed during site visits and one plant reported this procedure based on dcp and industry survey data.

Closed formation of wet batteries (single and double fill) was reported to produce a process wastewater discharge at 40 of 78 plants. Data specific to these two formations are summarized in Figure V-4 (page 244). As these data show, over 70 percent of all plants reported zero discharge from single fill formation while 80 percent reported wastewater discharge from double fill formation. The median flow at discharging plants was similar, for both processes (0.28 l/kg for single fill and 0.45 l/kg for double fill). The more frequent occurrence of discharge of process wastewater from double fill is attributable to rinsing batteries after immersion filling or dumping of formation electrolyte.

Fill and Dump - The fill and dump process is used to produce damp batteries which are a part of the group of batteries commonly called dry-charged by manufacturers. These differ from dehydrated plate batteries (produced by open formation) in the degree of electrolyte removal and dehydration. The presence of some electrolyte in the damp batteries when they are shipped causes the degree of charge retention during long-term storage to be less than that of the dehydrated plate type. Damp 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 the formation electrolyte is removed from the battery, some manufacturers add chemicals to the battery in a second acid solution which is also 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. Thirteen plants supplied flow information on this process. One of the 13 reported zero discharge from the process. The average production normalized flow is 1.83 l/kg and the median is 1.49 l/kg.

Three plants visited after proposal practice fill and dump formation. One of these plants uses immersion filling techniques with an associated battery rinse. All three plants reuse the dumped acid electrolyte. At one of the plants, batteries are filled with a chemical solution to dry the plates after the formation electrolyte is dumped. This chemical solution is discharged to treatment.

Open Formation - Open formation has the advantage of having access to the battery plates during and after formation. Visual inspection of the plates during formation allows closer control of formation conditions than is possible during closed formation. More significantly, however, after open formation plates can be rinsed thoroughly to remove residual electrolyte and can then be thoroughly dried as is required for the manufacture of dehydrated plate batteries.

Wet - Open case formation is used in the manufacture of some wet batteries. Because problems of inhomogeneity in the plates are most pronounced during formation of larger plate sizes, open case formation for the manufacture of wet batteries is frequently used for the manufacture of industrial batteries with large electrodes.

Ten of the 16 sites submitting flow data for open formation wet batteries achieve zero discharge. The average production normalized flow is 0.36 l/kg and the median is 0.00 l/kg. Wastewater discharges from open formation for wet batteries result from periodic replacement of spent formation electrolyte, plate rinsing, formation area washdown, and wet air pollution control scrubbers. Three of the six discharging sites discharge wastewater from plate rinsing operations. Plate rinsing is done in tanks which are periodically (about once a month) emptied to treatment. Alternately, some sites use a light water spray to rinse plates. The discharge flows from these plate rinsing operations are much lower than the flows from open formation dehydrated battery plate rinsing where single or multi staged rinsing operations are often used to eliminate all acid from the battery plates. Three of the six discharging sites, which include one site which also discharges plate rinse water, discharge spent formation electrolyte. The remaining site discharges wastewater from wet scrubbers and formation area washdown. Wet scrubber discharges associated with formation are discussed under the wet air pollution control process element.

Dehydrated - Most open case formation is for the purpose of producing dehydrated plates. Immediately after formation, the plates are rinsed and dehydrated. These operations are particularly important for the (lead) negative plates which oxidize rapidly if acid and moisture are not eliminated. A variety of techniques including the use of deionized water are used to rinse the formed plates. Multi-stage rinses are frequently used to achieve the required degree of electrolyte removal. Drying often requires both heat and vacuum to achieve dehydration of the plates.

The most common and significant source of wastewater from open dehydrated formation is plate rinsing. Additional wastewater sources are from vacuum pump seals or ejectors, wet air pollution control scrubbers, formation area washdown, and periodic electrolyte discharge.

Forty-two plants provided flow data with regard to open dehydrated formation. Two of these sites achieve zero discharge. A wide range of flows were reported by the 40 discharge sites. The wide range of flows is due to a number of factors. A variety of plate rinsing techniques (single stage rinsing, multistage series rinsing, countercurrent cascade rinsing) are practiced in the subcategory. Water usage associated with single and multi-stage series rinses is greater than that associated with countercurrent cascade rinsing. At some sites, the rinse tanks are agitated by bubbling air through sprayers or repeatedly lifting plates in and out of the tanks. Rinse tank agitation lowers the water usage associated with plate rinsing. The use of flow controllers also lowers water usage. Some sites discharge water from vacuum pump seals and ejectors used for dehydrating plates. Vacuum pump seal or ejector water significantly increases the flow from open dehydrated formation. The average production normalized flow is 28.26 l/kg and the median is 11.05 l/kg.

Seven of the sites visited after proposal use open dehydrated formation. All of these sites use plate rinses. One of the sites uses treated water for plate rinsing. Three sites use wet air pollution control scrubbers to remove acid fumes and mist, while at one site electrolyte is periodically discharged to treatment. None of the plants have a discharge associated with vacuum pump seals or ejectors.

Plate Soak - After curing, and usually the preliminary step for open formation, plates may be soaked in a sulfuric acid solution to enhance sulfation and improve mechanical properties. Plate soaking may be done in the battery case, a formation tank, or in a separate vessel, and is usually done for plates greater than 0.25 cm (0.10 inches) thick. Wastewater results from periodic discharge of the spent soaking acid. Wastewater flow data for plate soaking was collected after proposal from three sites. Assuming a monthly replacement of soaking acid, a production normalized flow for plate soaking was calculated for each site. The average of the three production normalized flows is 0.026 l/kg and the median is 0.021 l/kg.

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, 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 resin, rubber cement, or with a bituminous sealer; vents are installed; and the battery posts are welded or "burned" in place. Partial assembly prior to closed formation is the same as semi-assembly. Final sealing of the case and installation of vent covers is accomplished after formation. Wastewater discharges from battery assembly result from using wet scrubbers to control fumes generated from casting terminals and connector straps (small parts casting) and welding battery posts. These wet scrubbers are discussed later under the wet air pollution control process element.

Battery Wash. Many plants wash batteries in preparation for shipment. Plants which do not wash batteries generally produce dehydrated plate batteries, or extensively use contact cooling in formation precluding the necessity to wash. Batteries are washed primarily to remove sulfuric acid spilled on the outside of the battery case. Detergent is used at some plants to remove oil and grease. The battery wash process element is divided into two subelements, battery wash with water only, and battery wash with detergent.

Battery Wash with Water Only - Forty-four plants reported flow data for water only battery washes. One of these plants achieves zero discharge. This plant reuses battery wash water in acid cutting. The average production normalized flow for this process is 3.47 l/kg and the median is 0.59 l/kg. The magnitude of the discharge flow from battery washing is related to a number of factors. Factors which tend to reduce the discharge flow are as follows:

- Use of a switching device (mechanical or electrical) to stop the flow of water when batteries are not in the battery washer.
- Use of appropriate types of spray nozzles to properly disperse the rinsewater.
- Recycle wash water back to the battery washer.

Seven of the sites visited since proposal operate water only battery washes. All of these sites discharge wash water. One site uses an electrical switching device to reduce the discharge flow. Another site recycles the wash water with an overflow stream to treatment.

Battery Wash with Detergent - Twenty-two plants reported flow data for detergent battery washes. All of these plants discharge the detergent wash water. The average production normalized flow for this process is 1.70 l/kg and the median is 0.90 l/kg. Five of the sites visited after proposal operate detergent battery washes.

Floor Wash. Many battery plants use power floor scrubbers to clean floor areas. Power floor scrubbers are sometimes not used in areas such as (1) formation areas because acid spills tend to corrode these machines and (2) those areas where it is not practical to use a machine scrubber. Instead, high pressure water hoses are used to spray equipment and floors in these areas. Wastewater discharges associated with both power scrubbers and hoses are considered under floor wash.

A total of 13 sites reported flow data with regard to floor washing. Two sites reported no discharge from floorwash operations. The average production normalized flow from floor washing is 0.11 l/kg while the median flow is 0.13 l/kg. At some sites, floor wash flows and formation area washdown flows are not distinquishable. For those sites, the flow associated with formation area washdown was included in the floor wash flow.

Floor wash information was obtained from twelve of the sites visited after proposal. Ten sites have power floor scrubbers and 2 sites use only hoses. Five of the 10 sites use power scrubbers to clean all floor areas including the formation area. The remaining five sites use water hoses to washdown the formation and other miscellaneous areas.

Wet Air Pollution Control. Wet air pollution control (WAPC) devices are reported to be used in many lead battery plants to varying degrees in the following process activities: leady oxide production, grid manufacture, pasting, formation, battery assembly, battery washing, boost charging, acid mixing, and laboratories. From dcp, site visits, and telephone contacts with plant personnel, 80 sites reported using scrubbers in each area as follows: three sites for leady oxide production, 16 sites for grid manufacturing, 53 sites for pasting, 37 sites for formation (22 for open, 24 for closed, 15 for closed only), six sites for battery assembly, one site for battery washing, one site for boost charging, five sites for acid mixing, two sites for laboratories and one site for controlling paint fumes. Wastewater discharges from all lead subcategory process elements except laboratories are included in the wet air pollution control process element. Discharges from laboratory wet scrubbers are included in the laboratory process element.

Based on all collected data for wet air pollution control, most plants use wet scrubbers in two or less process element operations. Of the 80 plants which indicated the use of wet scrubbers, 73 use scrubbers in two or less operations. Pasting and formation represent the most common areas where wet scrubbers are used. The use of scrubbers in other areas was found to be rare, and site specific in nature. Grid manufacturing and battery assembly wet scrubbing is mostly (70 percent) represented by one company.

The scrubbers reported for battery washing and acid mixing are at sites associated with one corporation and are now used as static demisters without use of or generation of water. The site using a boost charging scrubber utilizes recycle of coalescer/demister washdown water with caustic addition, incurring infrequent low volume blowdown to treatment. No information is availalbe concerning the paint fume scrubber.

Based on telephone contacts and post-proposal data submittals by lead battery companies, primarily two types of scrubbers are used. These are as follows: (1) a static vessel of scrubber water, or internally recirculated water, through which fumes are sparged and (2) an acid mist or fume coalescer with intermittent washdown. The static vessel design typifies leady oxide production, grid manufacture, pasting, and battery assembly applications; the latter design typifies formation area air scrubbing. Wastewater from the static vessel design results from continuous overflow or periodic tank drainage. Wastewater from the fume coalescer results from intermittent mesh washdown or the use of a continuous water spray in the fan section of the scrubber.

Flow rates reported by plants in the subcategory for WAPC devices applied in pasting, grid manufacture, battery assembly, and leady oxide production varied significantly due to widely varying operating philosophies. The flow rates reported varied from 0 l/hr to 1,703 l/hr. After the dcp were submitted, three sites eliminated a total of five grid manufacturing, battery assembly and leady oxide WAPC scrubber operations and installed baghouses. Consequently, the current reported flow range is from 0 l/hr to 681 l/hr. All but two of these flows are equal to or less than 227 l/hr. About 40 sites report either an intermittent or unmeasureable stream which goes to wastewater treatment. The intermittency results from overflow or batch periodic draining to clean the tank and reclaim any residual lead-containing material.

The measured flows connote a continuous makeup and drainage rate for generally undefined reasons. From plant contacts with a site which used a scrubber for grid manufacturing, it was reported that a steady drainage was used at a time when a different mold release compound was being used, which generated significant loadings of soot upon application to the molds. The soot was the desired end product to lubricate the mold. This raised the particulate loading on their static scrubber system, purportedly requiring continuous makeup and drainage of water. Upon switching to cork release material, the need is negligible, and the flow has been set back, but still remains.

Reported flow rates from formation area scrubbers varied from negligible and intermittent to 68,130 liters per hour. This difference is due to a number of factors. Some sites operate the scrubber dry with intermittent washdown of the mesh. Some sites report no mesh washdown at all. Mesh washdown frequency varies from site to site resulting in varying wastewater flow rates. Other sites use a continuous water spray in the fan section of the scrubber. Based on vendor information, use of the continuous water spray results in a wastewater discharge that is 20 times greater than the discharge associated with the dry (intermittent washdown) operating mode.

The average and median production normalized flow for wet air pollution control was calculated using flow data for all scrubbers except for laboratories. Flow values for scrubbers used for more than one process area were counted once. The flow from one scrubber (68,130 l/hr) was not used to calculate the average and median production normalized flow values because water usage at this high level is considered excessive. The average production normalized flow for WAPC is 0.26 l/kg and the median is 0.00 l/kg, based on data from 56 scrubbers of which 32 do not discharge.

Battery Testing and Repair. Most finished batteries are tested prior to shipment to assure correct voltage and current capacity. Selected batteries may undergo more extensive tests including capacity, charge rate acceptance, cycle life, over-charge, and accelerated life tests. Batteries which are found to be faulty in testing may be repaired on site. These repair operations generally require disassembly of the battery and replacement of some component(s).

The conduction of tests and subsequent disassembly, inspection, and repair operations yield wastewater which is similar in character to discharges from formation operations. From industry survey data, 30 out of 65 plants report this activity demonstrating extensive involvement by the subcategory. The flow data which exists for this process is primarily from the dcp and sampling visits. Three sites reported flow values of 0.004 l/kg, 0.25 l/kg, and 0.34 l/kg. The average production normalized flow is 0.20 l/kg and the median is 0.25 l/kg.

Laboratory Testing. A number of quality control analyses are performed in laboratories at lead battery plants. These analyses involve both chemical and some physical property analyses of intermediate battery components and finished batteries. The following parameters are commonly analyzed at battery plants in this subcategory:

- Iron content of battery electrolyte,
- Particle size of leady oxide powder,
- Free lead content of lead oxide powder,
- Free lead content of cured plates,
- Lead sulfate content of paste,
- Lead sulfate content of formed plates
- Trace element contaminants contained in grids and lead strip.

Fifty-seven of the 65 industry surveys reported on-site laboratory facilities.

There are a number of wastewater sources associated with on-site laboratory facilities. Sources of process wastewater include instrument washing, general area cleanup, wet air pollution control discharge, and dumped battery electrolyte. Wet air pollution control scrubbers are used to remove lead dust and acid mist generated from wet chemistry tests performed under a ventilation hood. Blowdown from these scrubbers is considered under this process element rather than with the WAPC process element because scrubber use in the laboratory is intermittent and the flow is minimal.

Laboratory flow data was collected on post-proposal site visits to five sites. Flow data from four of the five sites were used to calculate an average normalized flow for laboratories of 0.003 l/kg. One flow value reported during the site visits was more than an order of magnitude greater than the other four values measured or reported. This large flow is not justified in terms of differences among sites testing and analysis procedures and was not considered in establishing the average normalized flow. The average normalized flow is a flow weighted average of the four reported or measured flows. This flow was calculated by adding the laboratory flows from the four sites and dividing by the total production associated with the four sites. Production data from 1982 was used to calculate the total production.

Truck Wash. Trucks are used to transport used batteries in connection with battery cracking (secondary lead subcategory of the nonferrous metals category) processes and to ship new and repairable batteries to and from battery manufacturing sites. These trucks are periodically washed generating a wastewater discharge. Only truck washing associated with battery manufacturing processes is considered in the battery manufacturing regulation. Truck washing at sites that have battery cracking or secondary lead smelting will be considered under nonferrous metals manufacturing.

From the industry surveys, 18 lead battery sites operate and washdown trucks and have no associated secondary lead smelter. Information on the number of trucks washed each day and water usage for truck washing was not provided in the industry surveys. However, water usage associated with truck wash operations was measured on two postproposal site visits. One of these sites uses about 150 liters of water per truck and the other sites uses about 125 liters of water per truck. These sites had associated secondary lead smelters. Although the measured flow values were from operations associated with a secondary lead smelter, the water usage data can also be used to estimate the use associated with battery manufacturing truck wash operations. Using 150 liters of water per truck and the number of trucks washed, a production normalized flow was calculated for each site. The average normalized flow from truck washing at these sites is 0.014 l/kg.

Hand Wash. In order to control employee exposure to lead, hand washing is a mandatory activity at most lead battery plants. Sixty-three of the 65 plants which responded to the industry survey reported that handwashing was a mandatory activity. No flow data with regard to handwashing was reported in the dcp or industry surveys. However, on two post proposal site visits, measurements of the volume of water used by plant personnel for handwashing were taken. At both plants, hand wash water usage was measured as 1.5 liters per employee per wash. This value was used to calculate an average normalized flow of 0.027 l/kg. The following procedure was used to calculate the average normalized flow:

- The number of production employees in required hand wash activites at each site was obtained from the industry survey (see Table V-4).

- Assuming 1.5 lites per employee per wash, and four washes per day, a daily hand wash flow for each site was calculated. This flow was converted to an annual flow by assuming 250 days of operation per year.

- The hand wash flows from each of the 63 sites were then added to determine the total annual hand wash flow for the subcategory.

- This total flow was divided by the total production associated with the 63 sites to determine the average normalized flow. Site production data from 1982 was used (when available) to calculate the total production. When 1982 production data was not available for a particular site, dcp production data was used.

<u>Respirator Wash</u>. At some battery plants, employees wear respirators to prevent the inhalation of lead dust and acid fumes. These respirators are usually cleaned and reused. Fifty-one plants which responded to the industry survey indicated that respirators are washed on-site. In addition, respirator wash information was obtained from twelve of the seventeen sites visited after proposal. The observed methods used for respirator wash were varied. Washing techniques included rinsing in lab sinks, laundering in conventional clothes washing machines, and sanitizing in ultrasonic machinery specifically used for respirator washing.

As with handwashing, there was limited respirator wash flow data available. No flow data were reported by plants in the dcp or industry surveys. However, the respirator wash flow was measured on two post proposal sampling visits and reported flow values were obtained from four additional sites. The average respirator wash water usage at these 6 sites is 4.6 liters per respirator. The average normalized respirator wash flow (0.006 l/kg) was calculated using the 4.6 liters per respirator value; 1982 (when available) or dcp production data; and industry survey data shown in Table V-4 on the number of respirators washed at each of the fifty-one sites reporting a respirator wash. The procedure used in calculating the average flow is identical to that used for hand washing.

<u>Laundry</u>. Eleven sites in the subcategory reported on-site laundering of work uniforms based on industry survey information (see Table V-4). Work uniforms include clothing, towels and other items distributed to each employee at the plant which are laundered together. Laundry water usage data was obtained on two post proposal sampling visits. The average water usage for

laundry at these two sites was 21.4 liters per uniform. The average normalized laundry flow (0.109 l/kg) was calculated in the same manner as the hand wash and respirator wash flows; the number of uniforms laundered per day was used as well as 1982 or dcp production data.

Process Integration

The different methods of carrying out each of the basic process steps discussed above may be combined to produce a large number of distinct process flow diagrams. Each plant 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 plants perform all process operations on-site. A significant number of plants purchase pasted battery plates from other plants. Conversely, some battery manufacturing plants produce only battery plates and do not assemble finished batteries.

When plates are formed by the plate manufacture, only assembly and electrolyte addition are performed by the battery manufacturer. Alternatively, the plates may be sold "green" (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 diagrams of Figures V-5 through V-9 (pages 245-249). In many cases, single sites produce multiple product types and therefore have process flows combining operations of more than one of these figures.

Wastewater Characteristics

Wastewater samples obtained at lead subcategory sites provided characterization of wastewater from the specific process operations addressed in the preceding discussion. Process wastewater samples were collected from five sites prior to proposal. Following proposal process element wastewater samples were obtained from three sites. These eight sites collectively represent the production of both SLI and industrial batteries and provide a broad view of the manufacturing processes in the lead subcategory. They also embody a variety of in-process control techniques including recirculation, low rate formation, recirculation of treated process wastewater, and several different wastewater treatment technologies. Sampling at these sites provides the basis for characterizing wastewater resulting from specific process operations and total lead battery manufacturing process wastewater. Interpretation of sampling results was aided by reference to additional information obtained from dcp, industry surveys and by visits to twenty-nine additional lead acid battery manufacturing sites at which process wastewater samples were not obtained.

Characteristics of process element wastewater were determined as a result of sampling performed both before and after proposal. These wastewater characteristics are summarized in Table V-5 (page 178). The concentrations and pollutant loadings in this table are in general, the average of all samples taken for the process element. Wastewater characteristics of each process element are discussed below.

Leady Oxide Production. Process wastewater from leady oxide production results from shell cooling of inadequately shrouded ball mills. Shell cooling water from an inadequately shrouded ball mill was sampled at Plant H. Pollutant concentrations and loadings in this wastewater are shown in Table V-5 under leady oxide production. The 0.5 mg/l lead concentration in this wastewater results from the entrainment and dissolution of lead dust from the ball mill. This concentration coupled with the large discharge flow of shell cooling water results in a significant lead loading (3.42 mg/kg).

Grid Manufacture. Mold Release Formulation - No samples of mold release formulation water were collected. As mold release formulation cleanup water does not come in direct contact with lead, pollutant concentrations should be minimal.

Direct Chill Casting - A sample of direct chill casting contact cooling water was collected from a catch tank. No overflow was observed from the catch tank and it was not due to be dumped when the sample was taken. The pollutant concentrations and loadings in the sample should adequately represent characteristics of direct chill casting contact cooling water. These concentrations and loadings are shown in Table V-5. As shown in Table V-5, pollutant loadings in this wastewater are minimal.

Lead Rolling - A sample of spent rolling emulsion was collected and pollutant concentrations and loadings are shown in Table V-5. The spent rolling emulsion is contract hauled by all of the five sites which roll lead in the subcategory.

Paste Preparation and Application. Wastewater samples were collected at five sites (three prior to proposal, two after proposal). Table V-6 (page 183) shows the wastewater characteristics of paste preparation and application area water at these sites. Pollutant loadings from the pasting wastewater at these five sites are shown in Table V-7 (page 185).

Wastewater samples at four of the sites (Plant D, Plant E, Plant F and Plant H) were obtained from trenches, sumps or holding tanks in which some settling of solids from washdown water had 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 material can be readily achieved by immediate settling. The wastewater stream at Plant A was sampled as the washdown water came off the equipment. This sample exemplifies the pasting raw waste concentration. The Plant A sample was used to characterize raw pasting water in Table V-5 and the other plant samples were used to estimate the effects of settling the paste stream.

Curing. Wastewater from curing was sampled during post proposal visits to two plants. Curing wastewater at one plant results from steam curing pasted plates while wastewater at another plant is from a water injected humidity oven. Curing wastewater characteristics and pollutant loads observed in sampling at these two sites are summarized in Tables V-8, and V-9 (pages 187 and 188).

Closed Formation Single Fill. Wastewater samples from single fill formation were obtained at Plant H. This site manufactures both SLI and industrial batteries using single fill formation. Contact cooling water is used to dissipate heat generated during charging for both battery types. Wastewater samples from the contact cooling water streams of both battery types were taken and pollutant concentrations and loadings were averaged. The average concentrations and loadings are presented in Table V-5.

Closed Formation Double Fill. Wastewater samples from double fill formation were obtained at Plant A. These samples were from a post-formation rinse of double fill batteries. Pollutant concentrations and loadings in the rinse are shown in Tables V-10 and V-11 (pages 189 and 190). No samples of double fill contact cooling water were taken, however, this wastewater is well represented by the single fill contact cooling water samples.

Closed Formation Fill and Dump (Damp Batteries). Wastewater samples from fill and dump formation were also taken at Plant A. Pollutant concentrations and loadings are also displayed in Tables V-10 and V-11. 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 current discharge is associated with a spray rinse similar to that used for double fill formation. Pollutant loadings in the fill and dump spray rinse are somewhat higher than those in the double fill rinse, 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 is included in the total raw wastewater stream sampled at the plant. Formation wastewater at that site results from contact cooling of batteries during a high rate formation process. Contact cooling water from fill and dump formation is also represented by the single fill samples from Plant H which were also from contact cooling wastewater.

Open Dehydrated Formation. Open dehydrated formation wastewater was sampled at Plants D, G, and H. Pollutant concentrations and loadings from these three sites are summarized in Tables V-12 and V-13 (pages 191 and 192). At Plant D, wastewater from open dehydrated formation results from a countercurrent cascade plate rinse. Plant G also discharges wastewater from a countercurrent cascade plate rinse and has an additional discharge associated with periodically rinsing residual plate materials out of open formation tanks (area washdown). These two wastestreams were sampled separately and pollutant concentrations in the combined open dehydrated formation wastewater at the site were calculated from a mass balance. Open dehydrated formation wastewater at Plant H results from a single stage plate rinse and an electrolyte bleed stream which results from a partial draining of each formation tank. The formation tanks are partially drained each day to enable plant personnel to physically get to the formed plates for removal. Both the electrolyte bleed and plate rinse were sampled separately and pollutant concentrations in the combined wastewater shown in Table V-12 were determined from a mass balance.

No samples of vacuum pump seal or ejector water were specifically collected, however total raw wastewater samples from Plant B includes vacuum ejector wastewater. Pollutant concentrations in this wastewater should be minimal because the seal water does not come in direct contact with lead.

Open Wet Formation. Wastewater from open wet formation was not specifically sampled. However, wastewater from this step is primarily a result of spent electrolyte discharges and plate rinsing. Pollutant concentrations in the electrolyte bleed sample from Plant H should be similar to discharge from open wet formation. This sample was used to determine the characteristics of open wet formation wastewater which are shown in Table V-5.

Plate soaking. Plate soaking wastewater was not specifically sampled. However, in terms of pollutant concentrations, discharges from plate soaking should be similar to those from open wet formation because both of these process elements discharge spent acid or electrolyte. Thus, the pollutant concentrations shown in Table V-5 are the same as the concentrations for open wet formation.

Battery Wash. Battery wash wastewater samples were collected from Plants A, D, F, and G. Plants D and G run detergent battery wash operations. Pollutant concentrations and loadings in the detergent battery wash water at these sites are shown in Tables V-14 and V-15 (pages 193 and 194). The detergent wash sample from Plant G was collected from the battery wash tank. This tank was being drained for cleaning and was nearly empty when the sample was taken. As a result of this, the sample was contaminated with sediment from the bottom of the tank and is not representative of overflow detergent battery wash water. The samples from Plant D included minimal flow contributions from battery repair and area washdown. Although the Plant D samples include these minimal flow contributions from battery repair and area washdown, they are more representative of detergent battery wash water than the sample from Plant G. Pollutant concentrations in the Plant G sample are, in general, nearly ten times greater than the concentrations in the Plant D samples. These high concentrations most likely result from the sample being contaminated with sediment from the bottom of the tank. Therefore, pollutant concentrations and loadings shown in Table V-5 for detergent battery washing are based on an average of the samples from Plant D.

Plants A and F use water only battery washes. Pollutant concentrations and loadings in the battery wash water are shown in Tables V-16, and V-17 (pages 195 and 196). Pollutant concentrations and loadings in Table V-5 for water only battery washing are based on the average.

Floor Wash. Floor wash samples were collected at Plants A, F, and H. Pollutant concentrations and loadings in these samples are presented in Table V-18, and V-19 (pages 197 and 198). The samples from Plants A and H represent wastewater from power floor scrubbers. At Plant F, both power floor scrubbers and water hoses are used to clean floors. Wastewater from both of these operations was sampled separately and a mass balance was performed to determine the characteristics of combined floor wash water at the site. Pollutant concentrations and loadings shown in Tables V-18 and V-19 for Plant F represent the combined floor wash water.

As mentioned above, the samples from Plants A and H represent wastewater from power floor scrubbers. Many sites also use hoses to wash certain floor areas; particularly formation area floors which may be space constrained or contain large amounts of acid spillage. The average pollutant concentrations shown in Table V-5 for floor wash water were calculated as follows:

- o Using flow data and concentration data from the hose water sample at Plant F, pollutant concentrations in combined floor wash water at Plants A and H were calculated (by a mass balance).
- o The calculated concentrations from Plants A and H were then averaged with the concentrations from Plant F.

Wet Air Pollution Control. Wet air pollution control water samples were collected at Plants F and H. Both of these samples were from formation area scrubber wastewater. Tables V-20 and V-21 (pages 199 and 200) show pollutant concentrations and loadings in these samples. These samples are used to characterize wet air pollution control wastewater from all lead battery manufacturing operations.

Battery Repair. Battery repair wastewater samples were collected from Plants A and D. Pollutant concentrations and loadings are shown in Tables V-22 and V-23 (pages 201 and 202).

Laboratory. A sample of laboratory wastewater was collected at Plant H. Laboratory wastewater at this site consists of instrument wash water, dumped battery electrolyte, and wet scrubber water. The sample was collected from a sink where laboratory instruments are washed and the battery electrolyte is dumped. The wet scrubber wastewater was not sampled. Pollutant concentrations in the combined laboratory waste stream (sink water plus wet scrubber water) were determined from a mass balance. The pollutant concentrations in the wet scrubber water were estimated for the mass balance. The calculated pollutant concentrations and waste loadings are shown in Table V-5.

Truck Wash. Truck wash samples were collected on sampling visits to Plants G and H. Pollutant concentrations and loadings in these samples are shown in Tables V-24 and V-25 (pages 203 and 204). The samples from these two sites were from truck wash operations at battery manufacturing sites associated with secondary lead smelters. Both sites haul scrap batteries to their secondary lead smelters. These scrap batteries are often damaged and leak electrolyte onto the floor of the trucks. The wastewater from washing these trucks is therefore more contaminated than the wastewater from washing trucks that are used solely for battery manufacturing purposes. A review of pollutant concentrations in the two samples shows that toxic pollutant concentrations in the sample from Plant G are generally lower than those from Plant H. Therefore, Plant G truck wash water is assumed to be more indicative of battery manufacturing wastewater. The average pollutant concentrations and loadings shown in Table V-5 for truck wash water are based on Plant G.

Hand Wash. Hand wash samples were collected from Plants G and H. These samples were collected from the sinks where employees wash their hands. Tables V-26 and V-27 (pages 205 and 206) show pollutant concentrations and loadings in the two samples.

Respirator Wash. Respirator wash samples were collected from Plants G and H. At Plant G, an ultrasonic cleaning machine is used which rinses and sterilizes the respirators. Separate samples of the rinse water and germicide (sterilizing solution) were taken. Pollutant concentrations in the combined respirator wash water were then determined from a mass balance. At Plant H, respirators are washed first in an acetic acid bath followed by double rinsing with water and final cleaning in an ultrasonic machine. A composite sample from the acetic acid bath, rinse water, and ultrasonic cleaning machine water (including the germicide solution) was taken. Tables V-28 and V-29 (pages 207 and 208) show the pollutant concentrations and loadings in respirator water at these sites.

Laundry. Laundry wastewater samples were also collected from Plants G and H. Tables V-30 and V-31 (pages 209 and 210) show the pollutant concentrations and pollutant loadings in this wastewater.

Total Process Wastewater Discharge and Characteristics

Flow - Total plant discharge flows range from 0 to nearly 62,000 l/hr with a median value of 1,640 l/hr. Production normalized discharge flows range from 0 to 78 l/kg with a median of 0.97 l/kg. Discharge flow from each plant in the subcategory is shown in Table V-32 (page 211). Approximately 30 percent (57 plants) of all plants in the subcategory reported zero process wastewater discharge. Most of these zero discharge plants were plants which only purchased plates and assembled batteries (17 plants) or plants which produced only wet batteries and generally employed single-fill formation (20 plants). Of the 57 plants, 26 plants indicated that no process wastewater was generated. Seven others indicated that wastewater was recycled and reused. The remaining plants employ evaporation or holding ponds (5 plants), discharge to dry wells, sumps, septic tanks or cesspools (13 plants), contract removal of process wastewater (2 plants), disposal of wastewater in a sanitary landfill (1 plant), or did not specify the disposition of process wastes (3 plants). Among discharging plants, only twelve were direct dischargers. All other discharging plants introduce process wastewater into POTW.

Raw Wastewater Characteristics - Total process wastewater characteristics determined from the analysis of samples collected at Plants A, B, C, D, E, F, G, and H are presented in Table V-34 (page 220). Pollutant loads determined by sampling at each of these sites are presented in Table V-35 (page 223). These data represent the process wastewater stream discharged to treatment at Plants A through F. The total process wastewater stream for Plants G and H include both process wastewater discharged to treatment and process wastewater that is not discharged to treatment. Minimal amounts of process wastewater resulting from personal hygiene activities bypass treatment at Plants A through F. However, personal hygiene streams were not sampled at these six sites and therefore were not included in the total process waste stream. Pollutant loadings from personal hygiene wastewater are minimal (as shown in Tables V-27, V-29, and V-31) and therefore the concentrations and loadings shown in Tables V-34, and V-35 for these six sites adequately represent the total process waste stream. Wastewater streams which are completely recycled such as pasting wastewater are not included in the total waste stream.

Large differences in wastewater volume and in pollutant concentrations among these eight sites are evident. The differences may be understood by examining the manufacturing process and wastewater management practices at each site.

Plant A manufactures wet and damp batteries and practices extensive in-process control of wastewater. Pasting equipment and area washdown at this plant is treated in a multistage settling system and is 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 with 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 to 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 battery repair area. The total wastewater from this plant, which is represented in Tables V-34 and V-35, includes wastewater flowing to wastewater treatment, the battery rinses and wash water, and the repair area cleanup wastewater, 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 plant. Significantly, the wastewater treatment system includes an evaporation pond allowing the achivement of zero pollutant discharge from this plant.

Plant B manufactures a high percentage of dehydrated plate batteries but also practices significant in-process water use control. 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 the filling area and battery case washing. Open-case formation and plate dehydration operations generate most of the process wastewater. The wastewater sources are plate rinsing, fume scrubbers, formation area washdown, and a vacuum ejector used in dehydrating the formed, rinsed plates. Partially treated wastewater is recycled from the wastewater treatment system for use in the wet scrubbers, area washdown, and rinsing of 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 plant is only 46 percent of the raw wastewater volume shown in the table or approximately 4.0 l/kg.

The raw wastewater 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 leady 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 plant. The relatively high production normalized flow arises 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 water use control. Pasting area wash water is collected in a sump and pumped to central wastewater treatment at the plant. Aside from limited settling in the sump, this wastewater stream is neither recycled nor treated separately prior to combining with other process wastewater 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 wastewater 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 have electrolyte dumped after formation and are 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 wastewater at this plant was sampled as it entered wastewater treatment and includes all sources discussed above. The pasting wastewater is included in total process wastewater for this plant. This, together with differences in water conservation practices, appears to account for the differences observed in pollutant concentrations and pollutant loads between this plant and Plant A. Lead loadings, for example, are significantly higher at Plant C as a result of the introduction of pasting wastewater and wastewater from battery centrifuges into wastewater treatment, but raw wastewater concentrations are low due to the dilution afforded by the much higher wastewater volume at this plant (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 water use control techniques at this plant resulted in the generation of a relatively low volume of process wastewater. Pasting area and equipment wash water is not recycled at this plant, but is separately treated by settling before introduction into the 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 (open formation process) were formed during sampling at this plant. Open formation is followed by a two-stage countercurrent cascade rinse of the formed plates. They are dried in an oven without the use of 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, battery repair operations, and wastewater from an on-site laboratory.

Plant E manufactures only wet industrial batteries. In-process water use control techniques at this site reduce the ultimate discharge volume nearly 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 plant results only from washing the pasting equipment and floor areas. This wastewater is treated and recycled for use in washing the pasting area floors. Equipment is washed with deionized water. This practice results in a gradual accumulation of wastewater in the recycle system and necessitates occasional contract removal of some wastewater. The total process wastewater characterized in Tables V-34 and V-35 includes the wastewater from pasting equipment and area washdown. The sample used to characterize this wastewater was obtained from a wastewater collection pit in which settling of paste particles occurred. Therefore lowered lead and TSS concentrations were found. The total process wastewater characteristics presented in Tables V-34 and V-35 were calculated from analyses of all of the individual wastewater streams described above, including the pasting wastewater before settling.

Plant F manufactures wet SLI batteries. Pasting equipment and area washdown water is collected in a trench network, drains to a sump, and is pumped to wastewater treatment. Aside from limited settling in the trench network and sump, this wastewater is neither recycled nor treated separately prior to combining with other process wastewater streams. Wastewater is also generated from curing which goes to wastewater treatment. Batteries are formed at this site using the single fill, single charge technique. A controlled charging procedure is used which eliminates the need to use contact cooling water to dissipate heat, and results in a completely formed battery in approximately one day. The controlled charging procedure allows for a break in the middle of formation which allows the batteries to cool. Fumes from the formation area are vented to wet air pollution control scrubbers. The scrubbers operate without water except for periodic washdown of the mesh filters where acid fumes coalesce.

At Plant F, all batteries pass through a water only battery wash after formation. The battery wash water is recirculated through a small tank; an overflow stream from this tank is routed to wastewater treatment. The overflow stream is continuously discharged even when no batteries are being washed. Additional process wastewater discharges at this site result from floor and hand washing (floor washing is accomplished with both power floor scrubbers and hoses), grid manufacturing, and laboratory testing. All process wastewater is discharged to wastewater treatment except one process stream which is discharged directly to the sanitary sewer, and another process stream which is contract hauled. Pollutant concentrations and loadings for total battery manufacturing process wastewater at this site are presented in Tables V-34 and V-35.

These concentrations and loadings represent all battery manufacturing process wastewater which is discharged to treatment and includes the stream which is contract hauled. Hand wash wastewater was not sampled at this site and is not included in the total waste stream; however the contribution to the total process waste stream from hand washing is minimal. The high pollutant loadings in the total process waste stream are primarily due to the discharge of pasting equipment and area washdown water. This single wastewater source accounts for over 75% of the lead loading in the total process waste stream.

Plant G manufactures both SLI and industrial batteries and employs closed and open formation processes. Pasting and area washdown wastewater, which is not recycled at this site, along with curing wastewater is discharged to treatment. Several in-plant water use control techniques are practiced at this site. For single fill formation, a controlled charging procedure is used which eliminates the need for contact cooling water. The batteries, which are charged in racks, are charged slowly for a few hours initially; the charging rate is then increased for several hours and then decreased for several more hours. Overall formation time is about three days. A wet scrubber is used to remove fumes generated during the single fill charging procedure. Wet scrubber water is treated with caustic and recycled. No blowdown from the scrubber system was observed during sampling. Both wet and dehydrated plate industrial and SLI batteries are produced by open formation. Two stage countercurrent cascade rinse operations are used to rinse plates prior to dehydration. These rinse tanks are agitated to ensure proper mixing and lower water usage. In the production of dehydrated SLI batteries, treated water from the wastewater treatment system is used for the countercurrent plate rinse. Thus, this plate rinse is ultimately a zero discharge operation. Both SLI and industrial plates are dehydrated following plate rinsing without the use of vacuum pump seal or ejector water.

Pollutant concentrations and loadings in the total process waste stream at this site are presented in Tables V-34, and V-35. The concentrations and loadings in this waste stream represent both wastewater discharged to treatment and wastewater from handwash, respirator wash, laundry, truck wash and laboratory testing operations which is not discharged to the central treatment system. Pollutant loadings in the total raw waste stream are comparable to those from Plant D, which also produces dehydrated batteries. These loadings, although fairly low, could be reduced further if additional in-plant water use control practices such as recycle of pasting area cleanup water were implemented.

Plant H manufactures both SLI and industrial batteries and employs closed and open formation processes. Leady oxide is produced by both the Barton and ball mill processes. In the ball mill process, a large volume of process wastewater is produced from shell cooling of an inadequately shrouded ball mill. Three pasting operations are performed onsite, two of which discharge equipment and area washdown water after limited settling. In the third pasting operation, the equipment and area washdown water is collected, settled, and reused in pasting area washdown. There were plans to install a recycle system for one of the discharging pasting operations but this system was only partially implemented at the time of sampling. Both SLI and industrial batteries are produced in single fill formation operations which use contact cooling water to dissipate heat generated during high rate formation. Two different cooling configurations are used for the single fill operations. In one operation, a once-through cooling configuration is used which results in a large discharge of process wastewater. In the second single fill operation, the cooling water discharge is significantly reduced by recycle through a water softening system. Dehydrated plate batteries are also produced at this site. Wastewater discharge from the dehydrated plate operation results from a single stage plate rinse and bleeding electrolyte from the formation tanks. No vacuum pump seal or ejector water is used in plate dehydration. Additional battery manufacturing process wastewater sources at this site result from wet air pollution control, hand and floor washing, respirator washing, and on-site laundry facilities.

Tables V-34 and V-35 present pollutant concentrations and loadings in the total battery manufacturing process waste stream. These concentrations and loadings represent all battery manufacturing process wastewater discharged at this site. As shown in Table V-35, pollutant loadings are fairly high due to inefficient water use in a number of processes.

A statistical summary of the total raw wastewater characteristics observed at these sites is presented in Table V-36 (page 226). 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-37 (page 227).

Wastewater Treatment Practices and Effluent Data Analysis

Dcp and Industry Survey Data - Plants in the lead subcategory employ a variety of end-of-pipe treatment technologies shown in

Table V-33 and in-process control techniques, and they achieve widely varying effluent quality. End-of-pipe treatment practices employed include pH adjustment, chemical precipitation, settling using a variety of devices, filtration, flotation, and reverse osmosis. In-process water use control techniques include segregation and treatment or recycle of specific wastewater streams and process modifications to eliminate points of water use and discharge. Most plants in the subcategory, which produce a process wastewater discharge, discharge to POTW. Dcp and industry survey response showed some significant differences between plants discharging to POTW and direct dischargers both in terms of treatment practices and effluent performance achieved. Direct dischargers generally provide more extensive wastewater treatment and control 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-three plants reported the use of pH adjustment and settling or pH adjustment and filtration for solids removal. These filtration units generally serve as primary solids removal -- they do not function as polishing filters following settling which are usually designed to achieve very low effluent pollutant concentrations.

Effluent quality data provided in dcp for plants practicing pH adjustment and settling are presented in Table V-38 (page 228). While the dcp did not in general provide sufficient data to allow meaningful evaluation of treatment system design and operation parameters, some characteristics 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 indicate that few discharges are at the 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 values for 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-38 clearly indicate that the sedimentation systems employed by some plants 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 direct and indirect dischargers corresponds to differences in the severity of regulations presently applied to these two groups of plants. This difference indicates that the variations in the data reflect variations in treatment design and operating practice rather than difference in attainable levels of pollutant reduction at plants in this subcategory.

Effluent quality data provided in industry surveys for plants practicing pH adjustment and settling are presented in Table V-39 (page 229). In general, the data provided in the industry surveys corresponds closely with that provided in dcp. Less than one third of the plants reported an effluent pH at the values appropriate for efficient removal of lead by precipitation. The effluent TSS values are also high indicating inadequate operation of the settling device. Plants which introduce their wastewater into POTW reported effluent lead concentrations ranging from 0.1 mg/l to 6.0 mg/l; with an average of 1.8 mg/l. Plants discharging to surface waters reported effluent lead concentrations ranging from 0.09 mg/l to 0.47 mg/l, with an average of 0.23 mg/l. Effluent quality data provided in the industry surveys support the conclusion drawn from the dcp data; that variations in data reflect variations in treatment design and operation rather than differences in attainable levels. Clearly, direct dischargers are more carefully operating treatment systems and are obtaining better lead effluent concentrations than indirect dischargers using the same treatment technologies.

Table V-40 (page 230) presents effluent quality data from dcp 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.

Effluent quality data provided in industry surveys for plants practicing pH adjustment and filtration are presented in Table V-41 (page 231). As was true for the dcp data, effluent lead concentrations for plants practicing pH adjustment and filtration are generally lower than plants practicing pH adjustment and settling and the data exhibits less variability. Plants which discharge wastewater directly reported lower effluent lead concentrations (average 0.27 mg/l) than those which discharge to a POTW (average 0.93 mg/l).

In the dcp, twenty-two plants reported the introduction of process wastewater into POTW after pH adjustment without the removal of suspended solids. Effluent quality data were provided by eleven of these indirectly discharging plants as shown in Table V-42 (page 232). This table also shows effluent data from one plant which reported process wastewater discharge to a POTW without treatment. Effluent lead concentrations reported in the dcp range from 1.0 mg/l to 29.8 mg/l and average 10 mg/l.

Industry survey effluent quality data for plants practicing only pH adjustment before discharge are presented in Table V-43 (page 233). Eighteen indirect dischargers reported the use of pH adjustment only with none of these plants reporting operation in the desired pH range of 8.8 to 9.3. Effluent lead concentrations range from 1.25 mg/l to 20 mg/l, with an average 5.3 mg/l. The effluent concentrations reported for these indirect dischargers practicing pH adjustment only are comparable to the effluent concentrations reported by indirect dischargers who practice pH adjustment and settling. This clearly indicates that settling devices are being improperly operated and controlled at lead battery plants.

Several plants provided data in dcp indicating the use of wastewater treatment systems other than those discussed above. These included sulfide precipitation, flotation separation, and reverse osmosis. One plant 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, the in-process controls were often not clearly shown. In many dcp in-process controls were deduced from process line descriptions and the presence of wastewater sources similar to those of plants which were visited for on-site data collection. As a result, the extent to which techniques such as low-rate charging without contact cooling water are used, cannot be defined from the dcp. One in-process control technique which could be identified in many dcp was segregation of process wastewater from pasting area and equipment washdown and subsequent settling and reuse of this wastewater stream. Approximately 30 percent of the plants reporting wastewater discharges indicated this practice. Those plants using this in-process technique are identified in Tables V-38, V-40 and V-42. The data in Tables V-38 and V-40 do not show significantly lower effluent lead concentrations from plants recycling pasting wastewater although raw wastewater concentrations and pollutant loads are significantly reduced by this practice as demonstrated by the data in Table V-42. This further substantiates the observation that effluent quality at existing lead subcategory plants is primarily determined by process flow practices, treatment system design, and operating parameters.

Additional in-process control techniques which are indicated in the dcp 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; low-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 and is presumed to exist at other plants 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 25 percent of those plants which practiced dehydrated plate manufacture and supplied process diagrams in their dcp. The production normalized flows resulting from these rinses are usually not significantly lower than those resulting from single stage or unspecified rinses. Since the spillage of electrolyte on battery cases necessitates removal of the spilled acid prior to shipment to allow safe handling of the battery, it may be concluded that where wet batteries are shipped and battery wash discharges are not reported, 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 low-rate charging is indicated at a number of battery manufacturing plants which did not indicate contact cooling wastewater from wet-charge formation processes. Finally, approximately 85 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 plants either achieve satisfactory plate drying without the use of seal or ejector water or recirculate water used for these purposes.

<u>Visited and Sampled Plants</u> - Wastewater treatment system effluent was sampled at eight visited battery manufacturing sites (three visited before proposal and five visited after proposal). At two sites, Plants G and H, wastewater from on-site secondary lead smelters is combined with battery manufacturing wastewater prior to treatment. Pollutant concentrations in the combined influent to wastewater treatment at these sites are shown in Table V-44. At Plant F, wastewater is held in equalization ponds with several days retention time prior to treatment. These ponds are not well

agitated and thus some settling out of solids occurs. Pollutant concentrations in the effluent from these ponds represent the influent to wastewater treatment at Plant F. These concentrations have also been included in Table V-44 to provide a description of the influent to treatment at Plant F. Pollutant concentrations in the treated effluent at each site are presented in Table V-45. These sites all use wastewater treatment systems based on chemical precipitation and solids removal but have implemented a number of different solids removal techniques.

Plant B uses a tubular cloth filter from which solids are continuously removed by the flow of the wastewater which becomes progressively more concentrated as clarified water permeates through the filter. This system was reported to be highly effective in the dcp data from this site. During sampling, however, excessive solids levels had been allowed to build up in the system and solids were 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.

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 plant.

Plant F also employs pH adjustment (with caustic) and subsequent filtration through a diatomaceous earth pre-coat filter press. It was observed during the visit to this site that the precipitation pH was 7.5 standards units. The best overall removal of toxic metals occurs when the precipitation pH is in the range of 8.8 to 9.3 standards units. It would appear that plant personnel have elected to operate at this low pH not to optimize toxic metals removals but rather to minimize the alkaline load discharged to the POTW. Despite these practices, however, lead was not detected in the sampled effluent from this site. Industry survey data from this site indicate an average lead effluent of 0.25 mg/l. This high effluent concentration is most likely caused by the low precipitation pH.

Plant G employs a clarifier for solids removal. This site does not practice sludge recycle to the clarifier influent or mix tank, a practice that is widespread in the battery manufacturing category as well as many others. Recycle of a portion of the sludge is critical in floc formation in the clarifier. This site's failure to do so limits its ability to effectively remove toxic metals. In addition, this site was adding polyphosphates to chelate calcium and to prevent it from precipitating in treated wastewater which was reused. The addition of this chemical or any other chelating agent impedes the precipitation and removals of metals including lead. This explains the high lead concentrations in the effluent from two of the sampling days.

Plant H uses two conventional clarifiers and a lamella separator followed by a polishing lagoon to remove precipitated solids from wastewater. As the data show, this system was operating normally during the sampling period.

At Plant I, wastewater is treated by pH adjustment, clarification, and filtration. Two operational problems were observed at this site. First large solids were observed exiting the clarifier. This is generally an indication of short circuiting or the need of a coagulant aid (such as iron salts) to enhance the settling properties of the precipitants. Second, the pH of the effluent from the clarifier is lowered by the addition of sulfuric acid prior to being introduced to the filter. This results in redissolution of toxic metals. Despite these operational problems, lead was not detected in the effluent from this site. However, industry survey data indicate the average lead concentration in the effluent from this site is 0.697 mg/l. This high effluent value is a direct result of the operational problems discussed above.

Plant J uses a clarifier with tube settlers to remove precipitated solids. During the visit to this site, the precipitation pH was observed to be 7.5. As discussed previously, this is below the expected range for solids removal. The tube settler used for primary solids removal was observed to be laden with solids. This impedes the manner in which the tube settler removes solids. In addition, the clarifier at this site is designed for continuous operation however it was operated intermittently during the visit.

Data from Plants B and D illustrate the importance of pH as an operating parameter for the removal of lead by chemical precipitation. Both Plants B and D (as well as Plant F and I) were observed to provide treatment at pH values considerably lower than in desirable for lead precipitation, a condition reflected in the poor effluent performance observed by 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.

After evaluating all dcp and plant visit effluent data the conclusion is made that although plants which discharge have treatment equipment in-place, the operation and maintenance of most of these systems is inadequate for treating lead subcategory pollutants.

TABLE V-1

SCREENING AND VERIFICATION ANALYSIS TECHNIQUES

Pollutants	Screening Analysis Methodology	Verification Analysis Methodology
1. Acenaphthene	SP	
2. Acrolein	SP	
3. Acrylonitrile	SP	
4. Benzene	SP	
5. Benzidine	SP	
6. Carbon Tetrachloride (Tetrachloromethane)	SP	
7. Chlorobenzene	SP	
8. 1,2,4-Trichlorobenzene	SP	
9. Hexachlorobenzene	SP	
10. 1,2-Dichloroethane	SP	
11. 1,1,1-Trichloroethane	SP	
12. Hexachloroethane	SP	
13. 1,1-Dichloroethane	SP	VP: L-L Extract; GC, ECD
14. 1,1,2-Trichloroethane	SP	VP: L-L Extract; GC, ECD
15. 1,1,2,2-Tetrachloroethane	SP	
16. Chloroethane	SP	
17. Bis(Chloromethyl) Ether	SP	
18. Bis(2-Chloroethyl) Ether	SP	
19. 2-Chloroethyl Vinyl Ether (Mixed)	SP	
20. 2-Chloronaphthalene	SP	
21. 2,4,6-Trichlorophenol	SP	
22. Parachlorometa Cresol	SP	
23. Chloroform (Trichloromethane)	SP	
24. 2-Chlorophenol	SP	
25. 1,2-Dichlorobenzene	SP	
26. 1,3-Dichlorobenzene	SP	
27. 1,4-Dichlorobenzene	SP	
28. 3,3-Dichlorobenzidine	SP	
29. 1,1-Dichloroethylene	SP	
30. 1,2-Trans-Dichloroethylene	SP	VP: L-L Extract; GC, ECD

TABLE V-1

SCREENING AND VERIFICATION ANALYSIS TECHNIQUES

Pollutants	Screening Analysis Methodology	Verification Analysis Methodology
31. 2,4-Dichlorophenol	SP	
32. 1,2-Dichloropropane	SP	
33. 1,2-Dichloropropylene (1,2-Dichloropropene)	SP	
34. 2,4-Dimethylphenol	SP	VP: GC - FID
35. 2,4-Dinitrotoluene	SP	
36. 2,6-Dinitrotoluene	SP	
37. 1,2-Diphenylhydrazine	SP	
38. Ethylbenzene	SP	
39. Fluoranthene	SP	SP
40. 4-Chlorophenyl Phenyl Ether	SP	
41. 4-Bromophenyl Phenyl Ether	SP	
42. Bis(2-Chloroisopropyl) Ether	SP	
43. Bis(2-Chloroethoxy) Methane	SP	
44. Methylene Chloride (Dichloromethane)	SP	
45. Methyl Chloride (Chloromethane	SP	
46. Methyl Bromide (Bromomethane)	SP	
47. Bromoform (Tribromomethane)	SP	
48. Dichlorobromomethane	SP	
49. Trichlorofluoromethane	SP	
50. Dichlorodifluoromethane	SP	
51. Chlorodibromomethane	SP	
52. Hexachlorobutadiene	SP	
53. Hexachlorocyclopentadiene	SP	
54. Isophorone	SP	SP
55. Naphthalene	SP	SP
56. Nitrobenzene	SP	
57. 2-Nitrophenol	SP	
58. 4-Nitrophenol	SP	
59. 2,4-Dinitrophenol	SP	
60. 4,6-Dinitro-O-Cresol	SP	

TABLE V-1

SCREENING AND VERIFICATION ANALYSIS TECHNIQUES

Pollutants	Screening Analysis Methodology	Verification Analysis Methodology
61. N-Nitrosodimethylamine	SP	
62. N-Nitrosodiphenylamine	SP	
63. N-Nitrosodi-N-Propylamine	SP	
64. Pentachlorophenol	SP	
65. Phenol	SP	VP: GC, ID
66. Bis(2-Ethylhexyl) Phthalate	SP	SP
67. Butyl Benzyl Phthalate	SP	SP
68. Di-N-Butyl Phthalate	SP	SP
69. Di-N-Octyl Phthalate	SP	SP
70. Diethyl Phthalate	SP	SP
71. Dimethyl Phthalate	SP	SP
72. 1,2-Benzanthracene (Benzo (a) Anthracene)	SP	SP
73. Benzo (a) Pyrene (3,4-Benzo-Pyrene)	SP	SP
74. 3,4-Benzofluoranthene	SP	SP
75. 11,12-Benzofluoranthene (Benzo (k) Fluoranthene)	SP	SP
76. Chrysene	SP	SP
77. Acenaphthylene	SP	SP
78. Anthracene	SP	SP
79. 1,12-Benzoperylene (Benzo (ghi)-Perylene)	SP	SP
80. Fluorene	SP	SP
81. Phenanthrene	SP	SP
82. 1,2,5,6-Dibenzathracene (Dibenzo (a,h) Anthracene)	SP	SP
83. Indeno (1,2,3-cd) Pyrene (s,3-0-Phenylene Pyrene)	SP	SP
84. Pyrene	SP	SP
85. Tetrachloroethylene	SP	

TABLE V-1

SCREENING AND VERIFICATION ANALYSIS TECHNIQUES

Pollutants	Screening Analysis Methodology	Verification Analysis Methodology
86. Toluene	SP	VP: L-L Extract; GC, FID
87. Trichloroethylene	SP	VP: L-L Extract; GC, ECD
88. Vinyl Chloride (Chloroethylene)	SP	
89. Aldrin	SP	
90. Dieldrin	SP	
91. Chlordane (Technical Mixture and Metabolites)	SP	
92. 4,4-DDT	SP	
93. 4,4-DDE (p,p'-DDX)	SP	
94. 4,4-DDD (p,p'-TDE)	SP	
95. Alpha-Endosulfan	SP	
96. Beta-Endosulfan	SP	
97. Endosulfan Sulfate	SP	
98. Endrin	SP	
99. Endrin Aldehyde	SP	
100. Heptachlor	SP	
101. Heptachlor Epoxide	SP	
(BHC-Hexachlorocyclohexane)		
102. Alpha-BHC	SP	
103. Beta-BHC	SP	
104. Gamma-BHC (Lindane)	SP	
105. Delta-BHC	SP	
(PCB-Polychlorinated Biphenyls)		
106. PCB-1242 (Aroclor 1242)	SP	
107. PCB-1254 (Aroclor 1254)	SP	
108. PCB-1221 (Aroclor 1221)	SP	
109. PCB-1232 (Aroclor 1232)	SP	
110. PCB-1248 (Aroclor 1248)	SP	
111. PCB-1260 (Aroclor 1260)	SP	
112. PCB-1016 (Aroclor 1016)	SP	
113. Toxaphene	SP	
114. Antimony	SP	
115. Arsenic	SP	

TABLE V-1

SCREENING AND VERIFICATION ANALYSIS TECHNIQUES

Pollutants	Screening Analysis Methodology	Verification Analysis Methodology
116. Asbestos	--	
117. Beryllium	ICAP	
118. Cadmium	ICAP	40CFR 136: AA
119. Chromium	ICAP	40CFR 136: AA
Hexavalent Chromium	--	40CFR 136: Colorimetric
120. Copper	ICAP	40CFR 136: AA
121. Cyanide	40CFR 136: Dist./Col. Mea.	40CFR 136: Dist./Col. Mea.
Cyanide Amenable to Chlorination		40CFR 136: Dist./Col. Mea.
122. Lead	ICAP	40CFR 136:AA
123. Mercury	SP	
124. Nickel	SP	40CFR 136:AA
125. Selenium	SP	
126. Silver	SP	
127. Thallium	SP	
128. Zinc	ICAP	40CFR 136:AA
129. 2,3,4,8-Tetrachlorodibenzo-P-Dioxin (TCDD)	SP	
Aluminum	--	40CFR 136:AA
Fluorides	--	Dist./I.E.
Iron	--	40CFR 136:AA
Manganese	--	40CFR 136:AA
Phenols	--	40CFR 136
Phosphorous Total	--	SM: Dig/SnC1
Oil & Grease	--	40CFR 136: Dist./I.E.
TSS	--	40CFR 136
TDS	--	40CFR 136
pH Minimum	--	Electrochemical
pH Maximum	--	Electrochemical
Temperature	--	--

TABLE V-1

SCREENING AND VERIFICATION ANALYSIS TECHNIQUES

Notes

40CFR 136: Code of Federal Regulations, Title 40, Part 136.

SP - *Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants*, U.S. EPA, March, 1977, Revised April, 1977.
VP - *Analytical Methods for the Verification Phase of BAT Review*, U.S. EPA, June, 1977.
SM - *Standard Methods*, 14th Edition.
ICAP - Inductively Coupled Argon Plasma.
AA - Atomic Absorption.
L-L Extract; GC, ECD - Liquid-Liquid Extraction/Gas Chromatography, Electron Capture Detection.
Dig/SnCl$_2$ - Digestion/Stannous Chloride.
Filt./Grav. - Filtration/Gravimetric
Freon Ext. - Freon Extraction
Dist./Col. Mea. - Distillation/pyridine pyrazolone colorimetric
Dist./I.E. - Distillation/Ion Electrode
GC-FID - Gas Chromatography - Flame Ionization Detection.
SIE - Selective Ion Electrode

TABLE V-2

SCREENING ANALYSIS RESULTS
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
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 Trichloroethane	0,5	ND	0.025	ND	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	ND
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

TABLE V-2

SCREENING ANALYSIS RESULTS
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
47. Bromoform		ND	ND	ND	ND
48. Dichlorobromomethane		*	*	*	ND
49. Trichlorofluoromethane		ND	ND	ND	ND
50. Dichlorodifluoromethane	0,4	ND	ND	ND	ND
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	NA
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

TABLE V-2

SCREENING ANALYSIS RESULTS
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
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
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	0.033	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	0.92	NA

TABLE V-2

SCREENING ANALYSIS RESULTS
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
Gold	-,-	ND	ND	ND	NA
Iron	-,-	<0.2	2.00	<0.2	NA
Magnesim	-,-	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	0.08	<0.005	NA
Phosphorus	-,-	0.040	0.58	0.04	NA
Sodium	-,-	<0.015	100.0	260.0	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

ND Not detected

NA Not analyzed (includes Xylenes & Alkyl Epoxides since laboratory analyses 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 ≤ .01 mg/l.

** Indicates ≤ .005 mg/l.

TABLE V-3

NORMALIZED DISCHARGE FLOWS FROM LEAD SUBCATEGORY ELEMENTS[1/]

Element	Mean Discharge (l/kg)	Median Discharge (l/kg)	Number of Plants Reporting Flow Data
Anodes and Cathodes			
Leady Oxide Production	0.37	0.00	41
Grid Manufacture			
Mold Release Formulation	0.006	*	2 (29)
Direct Chill Casting	0.0002	0.0002	1
Lead Rolling	0.006	0.006	1
Paste Preparation and Application	0.49	0.00	100
Curing	0.03	0.00	97
Closed Formation (In Case)			
Single Fill	0.28	0.00	43
Double Fill	0.92	0.44	35
Fill and Dump	1.83	1.49	13
Open Formation (Out of Case)			
Dehydrated	28.26	11.05	42
Wet	0.36	0.00	16
Plate Soaking	0.026	0.021	3
Ancillary Operations			
Battery Wash			
Detergent	1.70	0.90	22
Water Only	3.47	0.59	44
Floor Wash	0.11	0.13	13
Wet Air Pollution Control[2/]	0.26	0.00	56
Battery Repair	0.20	0.25	3
Laboratory	0.003	*	4
Truck Wash[3/]	0.014	0.014	2
Personal Hygiene			
Hand Wash	0.027	*	2 (63)
Respirator Wash	0.006	*	6 (51)
Laundry	0.109	*	2 (11)

1/ - Production normalizing parameter is total weight of lead used.

2/ - Discharge flow based on number of scrubbers from all process areas except laboratories.

3/ - Production normalizing parameter is weight of lead in trucked batteries.

* - Calculated as flow weighted average - no median available. (See text for discussion on calculation.)

( ) - Number of plants used to calculate l/kg flow per unit operation.

TABLE V-4

PERSONAL HYGIENE DATA FROM INDUSTRY SURVEY

Plant ID	Production Employees in Required Wash Up	Number of Hand Washes Per Day	Number of Employees Which Shower Per Day	Number of Uniforms Laundered Per Day	Laundry on Premise (P) or at Commercial Laundry (C)	Number of Gloves Cleaned Per Day on Premise	Number of Respirators Washed Per Day on Premise
A	180	4	65	120	C	0	60
B	193	4	12	22	C	0	7
C	75	4	75	75	P	0	22
D	60	3	60	64	C	0	0
E	125	4	30	85	C	0	30
F	160	3	160	160	C	0	0
G	148	3	148	148	C	0	75
H	130	4	20	60	C	0	25
I	256	4	256	256	C	0	45
J	90	4	60	100	C	0	0
K	130	4+	20	100	C	0	0*
L	144	3	144	144	P	0	170
M	350	4	225	250	C	25	80
N	62	4	62	62	C	0	0
O	225	4	150	150	C	0	60
P	400	3	400	8	C	0	6
Q	100	4	50	50	C	0	20
R	250	4	175	200	C	0	80
S	300	4	60	95	C	0	0
T	175-230	4	125-185	150	C	0	60
U	441	4	441	441	C	0	127
V	213	4	213	213	P	0	47
W	18	4	18	18	C	0	0*

TABLE V-4 (Continued)

PERSONAL HYGIENE DATA FROM INDUSTRY SURVEY

Plant ID	Production Employees in Required Wash Up	Number of Hand Washes Per Day	Number of Employees Which Shower Per Day	Number of Uniforms Laundered Per Day	Laundry on Premise (P) or at Commercial Laundry (C)	Number of Gloves Cleaned Per Day on Premise	Number of Respirators Washed Per Day on Premise
X	55	4	30	55	P	12	30
Y	219	4	43	6	C	0	10
Z	260	4	180	220	C	0	80
AA	175	4	175	180	C	0	65
AB	110	3	20	110	C	30	70
AC	772	3	645	675	P	0	145
AD	55	3	55	55	P	0	0
AE	71	4	52	71	C	50	12
AF	68	3	68	68	C	0	28
AG	390	4	130	30	C	0	2
AH	70	4	70	70	C	0	55
AI	280	4	200	140	C	0	60
AJ	470	3	470	470	P (72%) C (28%)	0	275
AK	30	4	12	25	C	0	0
AL	241	4	241	241	P	0	30
AM	245	3	245	245	C	0	145
AN	150	4	75	100	C	30	50
AO	205	3	205	205	C	0	85
AP	250	4	175	215	C	25	75
AQ	176	4	90	171	C	0	65
AR	218	3	120	120	P	0	95

TABLE V-4 (Continued)

PERSONAL HYGIENE DATA FROM INDUSTRY SURVEY

Plant ID	Production Employees in Required Wash Up	Number of Hand Washes Per Day	Number of Employees Which Shower Per Day	Number of Uniforms Laundered Per Day	Laundry on Premise (P) or at Commercial Laundry (C)	Number of Gloves Cleaned Per Day on Premise	Number of Respirators Washed Per Day on Premise
AS	75	3	30	50	C	0	8
AT	170	4	46	140	C	0	35
AU	250	4	175	215	C	25	75
AV	275	4	175	250	C	20	100
AW	275	4	200	200	C	120	80
AX	180	4	100	100	C	0	30
AY	112	4	112	112	C	0	60
AZ	2	6	2	50	P	0	0
BA	145	3	145	190	C	0	145
BB	225	4	190	200	C	0	50-100
BC	250	3	128	225	C	0	0
BD	80	3	80	80	C	0	0
BE	325	4	150	250	C	0	80
BF	300-350	4	225	275	C	25	75
BG	245	4	245	245	P	0	35
BH	98	3	74	111	C	0	42
BI	250	3	250	250	C	0	200
BJ	243	4	132	243	C	0	40
BK	200	4	50	200	C	0	12

*Disposable respirators are used.

NOTE: Two plants submitted no information on survey due to closure; total number of references was 65.

TABLE V-5

LEAD SUBCATEGORY
CHARACTERISTICS OF INDIVIDUAL PROCESS WASTES

		LEADY OXIDE PRODUCTION		DIRECT CHILL CASTING		LEAD ROLLING		PASTING		CURING	
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
	Flow (l/kg)		7.04		0.0002		0.0029		0.326		0.048
	Temperature (Deg C)	30.0	30.0	23.0	23.0	27.0	27.00	NA	NA	46.5	46.5
11	1,1,1-Trichloroethane	NA	NA	NA	NA	*	*	*	0.00	NA	NA
23	Chloroform	NA	NA	NA	NA	*	*	*	0.00	NA	NA
44	Methylene chloride	NA	NA	NA	NA	0.00	0.00	0.00	0.00	NA	NA
55	Naphthalene	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
65	Phenol	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
67	Butyl benzyl phthalate	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
68	Di-n-butyl phthalate	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
69	Di-n-octyl phthalate	NA	NA	NA	NA	0.00	0.00	0.00	0.00	NA	NA
78	Anthracene	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
81	Phenanthrene	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
84	Pyrene	NA	NA	NA	NA	0.00	0.00	*	0.00	NA	NA
114	Antimony	0.000	0.000	NA	NA	0.000	0.000	1.223	0.386	0.017	0.0009
115	Arsenic	0.000	0.000	NA	NA	0.000	0.000	0.000	0.000	0.007	0.0004
118	Cadmium	0.000	0.000	0.012	0.000	0.000	0.000	0.060	0.019	0.000	0.000
119	Chromium, Total	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA	0.000	0.000	NA	NA
120	Copper	0.000	0.000	0.41	0.0001	0.25	0.007	0.261	0.083	0.045	0.0025
122	Lead	0.50	3.52	1.2	0.0003	29.0	0.084	4020.0	1335.0	19.675	1.029
123	Mercury	NA	NA	NA	NA	0.000	0.0000	0.010	0.0031	NA	NA
124	Nickel	0.000	0.000	0.13	0.0000	0.003	0.0000	0.000	0.000	0.075	0.004
126	Silver	NA	NA	NA	NA	0.000	0.000	0.387	0.1240	NA	NA
128	Zinc	0.000	0.000	3.1	0.0007	1.4	0.0041	0.236	0.076	0.625	0.031
	Aluminum	0.000	0.000	0.54	0.0001	0.35	0.0010	NA	NA	4.05	0.222
	Iron	0.25	1.76	3.61	0.0008	7.3	0.021	3.56	1.153	4.625	0.269
	Manganese	0.062	0.444	0.06	0.0000	0.053	0.0002	NA	NA	0.070	0.004
	Phenols, Total	NA	NA	NA	NA	NA	NA	0.115	0.038	NA	NA
	Strontium	NA	NA	NA	NA	NA	NA	0.000	0.000	NA	NA
	Oil & Grease	1.49	10.5	6.0	0.0013	270.0	0.783	952.7	319.6	0.000	0.000
	Total Suspended Solids	0.62	4.4	8.0	0.0018	480.0	1.39	21883.3	7035.0	46.5	0.435
	pH, Minimum	NA	NA	NA	NA	NA	NA	7.7	7.7	NA	NA
	pH, Maximum	7.0	7.0	8.5	8.5	7.9	7.9	8.4	8.4	7.8	7.8

NA - Not Analyzed
* - ≤ 0.01

TABLE V-5 (Continued)

LEAD SUBCATEGORY
CHARACTERISTICS OF INDIVIDUAL PROCESS WASTES

		SINGLE FILL FORMATION		DOUBLE FILL FORMATION		FILL & DUMP FORMATION		OPEN WET FORMATION		OPEN DEHYDRATED FORMATION	
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
	Flow (l/kg)		5.717		0.45		1.295		0.36		7.912
	Temperature (Deg C)	30.0	30.0	19.0	19.0	19.0	19.0	30.0	30.0	45.0	45.0
11	1,1,1-Trichloroethane	NA	NA	*	0.00	0.00	0.00	NA	NA	*	0.00
23	Chloroform	NA	NA	*	0.00	0.00	0.00	NA	NA	8.0	0.00
44	Methylene chloride	NA	NA	*	0.00	0.00	0.00	NA	NA	0.00	0.00
55	Naphthalene	NA	NA	0.00	0.00	0.00	0.00	NA	NA	*	0.00
65	Phenol	NA	NA	0.00	0.00	0.00	0.00	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	*	0.00	0.006	0.006	NA	NA	0.064	0.920
67	Butyl benzyl phthalate	NA	NA	*	0.00	0.00	0.00	NA	NA	0.00	0.00
68	Di-n-butyl phthalate	NA	NA	*	0.00	*	0.00	NA	NA	*	0.00
69	Di-n-octyl phthalate	NA	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
78	Anthracene	NA	NA	0.00	0.00	0.00	0.00	NA	NA	*	0.00
81	Phenanthrene	NA	NA	0.00	0.00	0.00	0.00	NA	NA	*	0.00
84	Pyrene	NA	NA	0.00	0.00	0.00	0.00	NA	NA	0.00	0.00
114	Antimony	0.06	0.34	0.000	0.000	0.000	0.000	0.928	0.334	0.141	0.612
115	Arsenic	0.000	0.000	0.000	0.000	0.025	0.023	0.12	0.043	0.004	0.0051
118	Cadmium	0.000	0.000	0.003	0.001	0.005	0.007	0.037	0.013	0.002	0.0187
119	Chromium, Total	0.000	0.000	0.047	0.021	0.117	0.132	0.037	0.013	0.022	0.2308
	Chromium, Hexavalent	NA	NA	0.000	0.000	0.000	0.000	NA	NA	NA	NA
120	Copper	1.5	8.58	0.223	0.093	0.395	0.487	0.003	0.001	0.016	0.208
122	Lead	0.275	1.57	1.173	0.532	1.835	2.331	2.146	0.773	4.856	47.635
123	Mercury	NA	NA	0.005	0.0023	0.000	0.000	NA	NA	0.000	0.000
124	Nickel	0.000	0.000	0.024	0.011	0.091	0.100	0.696	0.251	0.050	0.5332
126	Silver	NA	NA	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000
128	Zinc	0.02	0.114	0.107	0.046	0.135	0.162	0.557	0.201	0.361	2.945
	Aluminum	0.15	0.086	NA	NA	NA	NA	0.278	0.100	0.118	0.962
	Iron	4.25	24.3	5.64	2.52	6.88	7.967	1.078	0.388	1.403	9.482
	Manganese	0.05	0.29	NA	NA	NA	NA	0.000	0.000	0.029	0.166
	Phenols, Total	NA	NA	0.035	0.014	0.021	0.027	NA	NA	0.01	0.159
	Strontium	NA	NA	0.000	0.000	0.000	0.000	NA	NA	0.000	0.000
	Oil & Grease	1.5	8.6	2.1	0.868	1.25	1.640	0.000	0.000	3.924	34.87
	Total Suspended Solids	22.5	128.6	5.0	2.376	10.5	12.65	148.95	53.6	87.256	582.5
	pH, Minimum	2.0	2.0	2.0	2.0	2.0	2.0	NA	NA	1.6	1.6
	pH, Maximum	2.0	2.0	2.7	2.7	2.3	2.3	1.7	1.7	3.2	3.2

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-5 (Continued)

LEAD SUBCATEGORY
CHARACTERISTICS OF INDIVIDUAL PROCESS WASTES

		PLATE SOAK		BATTERY WASH DETERGENT		BATTERY WASH WATER ONLY		FLOOR WASH		WET AIR POLLUTION CONTROL	
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
	Flow (l/kg)		0.026		0.61		0.439		0.034		0.109
	Temperature (Deg C)	30.0	30.0	28.0	28.0	19.0	19.0	24.0	24.0	26.0	26.0
11	1,1,1-Trichloroethane	NA	NA	*	0.00	*	0.00	0.00	0.00	NA	NA
23	Chloroform	NA	NA	*	0.00	*	0.00	0.00	0.00	NA	NA
44	Methylene chloride	NA	NA	*	0.00	0.00	0.00	*	0.00	NA	NA
55	Naphthalene	NA	NA	*	0.00	0.025	0.011	*	0.00	NA	NA
65	Phenol	NA	NA	NA	NA	0.00	0.00	0.00	0.00	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	0.034	0.020	0.006	0.002	*	0.00	NA	NA
67	Butyl benzyl phthalate	NA	NA	*	0.00	*	0.00	*	0.00	NA	NA
68	Di-n-butyl phthalate	NA	NA	*	0.00	*	0.00	*	0.00	NA	NA
69	Di-n-octyl phthalate	NA	NA	*	0.00	*	0.00	*	0.00	NA	NA
78	Anthracene	NA	NA	*	0.00	*	0.00	*	0.00	NA	NA
81	Phenanthrene	NA	NA	*	0.00	*	0.00	*	0.00	NA	NA
84	Pyrene	NA	NA	0.00	0.00	0.00	0.00	*	0.00	NA	NA
114	Antimony	0.928	0.024	0.123	0.068	0.01	0.003	0.333	0.156	0.165	0.014
115	Arsenic	0.12	0.003	0.043	0.022	0.003	0.0005	0.07	0.006	0.007	0.0005
118	Cadmium	0.037	0.001	0.001	0.001	0.001	0.0005	0.070	0.021	0.000	0.000
119	Chromium, Total	0.037	0.001	2.093	1.184	0.087	0.025	1.157	0.359	0.03	0.0025
	Chromium, Hexavalent	NA	NA	NA	NA	0.000	0.000	0.000	0.000	NA	NA
120	Copper	0.003	0.0001	1.517	0.830	0.322	0.166	0.670	0.182	0.075	0.0075
122	Lead	2.146	0.056	12.34	7.138	2.487	1.373	198.26	62.48	0.225	0.019
123	Mercury	NA	NA	0.000	0.000	0.0247	0.0079	0.000	0.000	NA	NA
124	Nickel	0.696	0.018	1.447	0.802	0.060	0.0178	0.765	0.230	0.04	0.003
126	Silver	NA	NA	0.001	0.0005	0.000	0.000	0.000	0.000	NA	NA
128	Zinc	0.557	0.015	3.393	1.818	0.632	0.1635	2.950	0.452	0.5	0.04
	Aluminum	0.278	0.007	NA	NA	0.17	0.031	5.782	0.326	0.45	0.065
	Iron	1.078	0.028	49.93	28.35	6.707	2.601	39.802	10.60	6.5	0.49
	Manganese	0.000	0.000	NA	NA	0.085	0.016	0.361	0.015	0.04	0.006
	Phenols, Total	NA	NA	0.021	0.012	0.017	0.008	0.095	0.003	NA	NA
	Strontium	NA	NA	0.000	0.000	0.013	0.008	0.000	0.000	NA	NA
	Oil & Grease	0.000	0.000	13.13	7.987	14.5	7.795	12.518	9.486	4.7	0.465
	Total Suspended Solids	148.95	3.87	107.8	68.43	42.0	24.60	631.555	427.5	16.5	1.8
	pH, Minimum	NA	NA	2.0	2.0	1.5	1.5	3.0	3.0	NA	NA
	pH, Maximum	1.7	1.7	12.0	12.0	4.6	4.6	9.1	9.1	1.8	1.8

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-5 (Continued)

LEAD SUBCATEGORY
CHARACTERISTICS OF INDIVIDUAL PROCESS WASTES

		BATTERY REPAIR		LABORATORY		TRUCK WASH		HAND WASH		RESPIRATOR WASH	
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
	Flow (l/kg)		0.10		0.0024		0.0027		0.0208		0.0166
	Temperature (Deg C)	32.0	NA	25.0	25.0	16.0	16.0	30.0	30.0	43.0	43.0
11	1,1,1-Trichloroethane	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
23	Chloroform	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
44	Methylene chloride	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
55	Naphthalene	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
65	Phenol	0.00	0.00	NA	NA	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.012	0.0015	NA	NA	NA	NA	NA	NA	NA	NA
67	Butyl benzyl phthalate	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
68	Di-n-butyl phthalate	0.007	0.00	NA	NA	NA	NA	NA	NA	NA	NA
69	Di-n-octyl phthalate	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
78	Anthracene	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
81	Phenanthrene	*	0.00	NA	NN	NA	NA	NA	NA	NA	NA
84	Pyrene	*	0.00	NA	NA	NA	NA	NA	NA	NA	NA
114	Antimony	0.128	0.0004	0.000	0.000	0.31	0.0008	0.23	0.006	0.0002	0.0000
115	Arsenic	0.05	0.005	0.000	0.000	0.05	0.0001	0.03	0.0007	0.00015	0.0000
118	Cadmium	0.116	0.0008	0.018	0.0000	0.04	0.0001	0.000	0.000	0.0002	0.0000
119	Chromium, Total	0.147	0.016	0.000	0.000	0.18	0.0005	0.01	0.0003	0.31	0.0085
	Chromium, Hexavalent	0.000	0.000	NA	NA	NA	NA	NA	NA	NA	NA
120	Copper	3.408	0.065	0.417	0.0010	1.2	0.003	0.875	0.019	0.175	0.008
122	Lead	13.532	0.132	5.01	0.0012	20.9	0.056	11.25	0.221	3.117	0.081
123	Mercury	0.0044	0.0000	NA	NA	NA	NA	NA	NA	NA	NA
124	Nickel	0.251	0.016	0.000	0.000	0.25	0.0007	0.025	0.0004	0.2	0.005
126	Silver	0.002	0.0000	NA	NA	NA	NA	NA	NA	NA	NA
128	Zinc	4.52	0.096	0.965	0.0023	1.58	0.004	0.83	0.019	0.412	0.008
	Aluminum	NA	NA	1.02	0.0024	37.8	0.102	0.20	0.005	0.000	0.000
	Iron	169.26	0.952	1.159	0.0028	1050.0	2.835	1.05	0.024	0.176	0.0045
	Manganese	NA	NA	0.000	0.000	7.2	0.019	0.000	0.000	0.000	0.000
	Phenols, Total	0.09	0.006	NA	NA	NA	NA	NA	NA	NA	NA
	Strontium	0.000	0.000	NA	NA	NA	NA	NA	NA	NA	NA
	Oil & Grease	35.46	0.919	39.88	0.0960	7.0	0.019	165.0	2.625	5.6	0.085
	Total Suspended Solids	314.26	1.947	723.45	1.74	2500.0	6.75	269.0	6.63	10.549	0.213
	pH, Minimum	2.7	2.7	NA	NA	NA	NA	NA	NA	NA	NA
	pH, Maximum	2.8	2.8	2.0	2.0	3.0	3.0	8.0	8.0	7.0	7.0

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-5 (Continued)

LEAD SUBCATEGORY
CHARACTERISTICS OF INDIVIDUAL PROCESS WASTES

LAUNDRY

		mg/l	mg/kg
	Flow (l/kg)		0.0885
	Temperature (Deg C)	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.105	0.009
115	Arsenic	0.01	0.0009
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.225	0.020
122	Lead	13.2	1.162
123	Mercury	NA	NA
124	Nickel	0.000	0.000
126	Silver	NA	NA
128	Zinc	0.58	0.050
	Aluminum	0.25	0.022
	Iron	0.95	0.083
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	49.2	4.211
	Total Suspended Solids	135.0	12.03
	pH, Minimum	NA	NA
	pH, Maximum	6.0	6.0

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-6

PASTING
WASTEWATER CHARACTERISTICS
mg/l

		PLANT A			PLANT D			PLANT E
	Stream Identification	Clean Up Water From Pasting Machine			In-Line Sump Under Pasting Machine			Holding Pit†
	Temperature (Deg C)	NA	NA	NA	29.0	NA	NA	NA
11	1,1,1-Trichloroethane	*	0.00	0.00	*	*	*	*
23	Chloroform	*	0.00	0.00	*	*	*	0.00
44	Methylene chloride	0.00	0.00	0.00	*	0.00	0.00	0.00
55	Naphthalene	*	*	*	0.020	0.012	0.016	0.00
65	Phenol	NA	0.00	NA	NA	NA	NA	0.00
66	Bis(2-ethylhexyl)phthalate	*	*	*	*	*	0.113	*
67	Butyl benzyl phthalate	*	0.00	0.00	0.00	0.00	0.00	*
68	Di-n-butyl phthalate	*	*	*	*	*	*	*
69	Di-n-octyl phthalate	0.00	0.00	0.00	0.00	*	0.00	0.00
78	Anthracene	*	0.00	*	*	*	*	0.00
81	Phenanthrene	*	0.00	*	*	*	*	0.00
84	Pyrene	*	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.000	3.670	0.000	0.000	0.310	0.130
115	Arsenic	0.000	0.000	0.000	0.000	0.000	0.000	NA
118	Cadmium	0.000	0.000	0.180	0.007	0.006	0.036	0.034
119	Chromium, Total	0.000	0.000	0.000	0.033	0.017	0.030	NA
	Chromium, Hexavalent	0.000	0.000	0.000	NA	NA	NA	0.000
120	Copper	0.120	0.083	0.580	0.025	0.025	0.190	NA
122	Lead	2700.0	6000.0	3360.0	280.0	208.0	254.0	13.40
123	Mercury	0.0200	0.000	I	0.000	0.000	0.000	0.0460
124	Nickel	0.000	0.000	0.000	0.027	0.016	0.024	NA
126	Silver	0.2600	0.1900	0.710	0.0100	0.0100	0.1800	0.0080
128	Zinc	0.038	0.160	0.510	0.780	0.540	0.410	3.880
	Aluminum	NA	NA	NA	NA	NA	NA	NA
	Iron	0.800	2.650	7.23	0.760	0.540	2.030	390.0
	Manganese	NA	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.085	0.150	0.110	0.061	0.079	0.069	0.020
	Strontium	0.000	0.000	0.000	0.000	0.000	0.023	0.000
	Oil & Grease	38.0	1620.0	1200.0	9.3	35.0	30.0	3.0
	Total Suspended Solids	10890.0	12450.0	42310.0	6600.0	20900.0	11000.0	184.0
	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
* - ≤ 0.01
† - Includes Some Floor Wash & Deionized Water Spillage (Approximately 2 Days Residence Time Before Treatment).

TABLE V-6 (Continued)

PASTING
WASTEWATER CHARACTERISTICS
mg/l

		PLANT F*	PLANT H**
	Temperature (Deg C)	23.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.12	0.02
115	Arsenic	0.004	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.12	0.000
122	Lead	850.0	384.0
123	Mercury	NA	NA
124	Nickel	0.000	0.000
126	Silver	NA	NA
128	Zinc	0.000	0.02
	Aluminum	0.080	0.000
	Iron	0.41	0.15
	Manganese	0.006	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	NA	160.0
	Total Suspended Solids	0.2	730.0
	pH, Minimum	5.5	NA
	pH, Maximum	6.0	6.0

NA - Not Analyzed

*Composite of aliquots collected from under paste application machine conveyor belt, paste area trenches, and belt bed under paste application machine.

**Discharge pipe from trench collection system in pasting area.

TABLE V-7

PASTING
WASTE LOADINGS
mg/kg

		PLANT A			PLANT D			PLANT E
	Stream Identification	Clean Up Water From Pasting Machine			In-Line Sump Under Pasting Machine			Holding Pit†
	Flow (l/kg)	0.311	0.351	0.316	0.058	0.063	0.064	0.218
	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	0.000	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	0.000	0.000	1.158	0.000	0.000	0.020	0.028
115	Arsenic	0.000	0.000	0.000	0.000	0.000	0.000	NA
118	Cadmium	0.000	0.000	0.057	0.000	0.000	0.002	0.007
119	Chromium, Total	0.000	0.000	0.000	0.002	0.001	0.002	NA
	Chromium, Hexavalent	0.000	0.000	0.000	NA	NA	NA	0.00
120	Copper	0.037	0.029	0.183	0.001	0.002	0.012	NA
122	Lead	840.0	2104.0	1060.0	16.26	13.18	16.25	2.920
123	Mercury	0.0062	0.000	I	0.0006	0.0006	0.0115	0.010
124	Nickel	0.000	0.000	0.000	0.002	0.001	0.002	NA
126	Silver	0.0809	0.0667	0.2244	0.0006	0.0006	0.0115	0.0017
128	Zinc	0.012	0.056	0.161	0.045	0.034	0.026	0.845
	Aluminum	NA	NA	NA	NA	NA	NA	NA
	Iron	0.249	0.929	2.282	0.044	0.034	0.130	85.0
	Manganese	NA	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.026	0.053	0.035	0.004	0.005	0.004	0.004
	Strontium	0.000	0.000	0.000	0.000	0.000	0.001	0.000
	Oil & Grease	11.82	568.2	378.7	0.540	2.205	2.217	1.919
	Total Suspended Solids	3388.0	4367.0	13350.0	383.3	1324.0	704.0	40.09
	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
† - Includes Some Floor Wash & Deionized Water Spillage (Approximately 2 Days Residence Time Before Treatment).

TABLE V-7 (Continued)

PASTING
WASTE LOADINGS
mg/kg

		PLANT F*	PLANT H**
	Flow (l/kg)	0.0508	0.0831
	Temperature (Deg C)	23.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.006	0.002
115	Arsenic	0.0002	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.006	0.000
122	Lead	43.0	31.9
123	Mercury	NA	NA
124	Nickel	0.000	0.000
126	Silver	NA	NA
128	Zinc	0.000	0.002
	Aluminum	0.004	0.000
	Iron	0.021	0.013
	Manganese	0.0003	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	NA	13.3
	Total Suspended Solids	0.11	60.7
	pH, Minimum	5.5	NA
	pH, Maximum	6.0	6.0

NA - Not Analyzed

*Composite of aliquots collected from under paste application machine conveyor belt, paste area trenches, and belt bed under paste application machine.

**Discharge pipe from trench collection system in pasting area.

TABLE V-8

CURING
WASTEWATER CHARACTERISTICS
mg/l

	Temperature (Deg C)	60.0	33.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.015	0.02
115	Arsenic	0.013	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.090	0.000
122	Lead	38.0	1.35
123	Mercury	NA	NA
124	Nickel	0.15	0.000
126	Silver	NA	NA
128	Zinc	0.95	0.3
	Aluminum	0.80	0.1
	Iron	9.0	0.25
	Manganese	0.14	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.000	0.000
	Total Suspended Solids	8.3	10.0
	pH, Minimum	NA	NA
	pH, Maximum	10.11	7.5

NA - Not Analyzed

TABLE V-9

CURING
WASTE LOADINGS
mg/kg

	Flow (l/kg)	0.0533	0.043
	Temperature (Deg C)	60.0	33.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.0008	0.0009
115	Arsenic	0.0007	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.005	0.000
122	Lead	2.0	0.058
123	Mercury	NA	NA
124	Nickel	0.008	0.000
126	Silver	NA	NA
128	Zinc	0.051	0.01
	Aluminum	0.426	0.018
	Iron	0.48	0.058
	Manganese	0.007	0.0003
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.000	0.000
	Total Suspended Solids	0.44	0.43
	pH, Minimum	NA	NA
	pH, Maximum	10.11	7.5

NA - Not Analyzed

TABLE V-10

DOUBLE FILL AND FILL & DUMP FORMATION
WASTE CHARACTERISTICS
PLANT A
mg/l

		DOUBLE FILL			FILL & DUMP	
	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
23	Chloroform	0.00	*	0.00	0.00	0.00
44	Methylene chloride	*	*	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	*	*	*	*	0.012
67	Butyl benzyl phthalate	*	*	0.00	0.00	0.00
68	Di-n-butyl phthalate	*	*	*	*	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	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.000	0.050
118	Cadmium	0.000	0.005	0.006	0.005	0.005
119	Chromium, Total	0.026	0.070	0.045	0.064	0.170
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0.000
120	Copper	0.100	0.170	0.400	0.330	0.460
122	Lead	0.960	1.710	0.850	1.710	1.960
123	Mercury	0.000	0.0150	0.000	0.000	0.000
124	Nickel	0.008	0.044	0.020	0.043	0.140
126	Silver	0.000	0.000	0.000	0.000	0.000
128	Zinc	0.060	0.083	0.180	0.100	0.170
	Aluminum	NA	NA	NA	NA	NA
	Iron	3.900	7.92	5.100	4.400	9.36
	Manganese	NA	NA	NA	NA	NA
	Phenols, Total	0.016	0.010	0.078	0.020	0.022
	Strontium	0.000	0.000	0.000	0.000	0.000
	Oil & Grease	1.0	1.1	4.2	1.3	1.2
	Total Suspended Solids	6.0	8.0	1.0	8.0	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
* - $\leq$ 0.01

TABLE V-11

DOUBLE FILL AND FILL & DUMP FORMATION
WASTE LOADINGS
PLANT A
mg/kg

		DOUBLE FILL			FILL & DUMP	
	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	0.011
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	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.000	0.046
118	Cadmium	0.000	0.002	0.002	0.008	0.005
119	Chromium, Total	0.013	0.032	0.017	0.108	0.155
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0.000
120	Copper	0.052	0.077	0.151	0.554	0.420
122	Lead	0.498	0.777	0.321	2.873	1.789
123	Mercury	0.000	0.0070	0.000	0.000	0.000
124	Nickel	0.004	0.020	0.008	0.072	0.128
126	Silver	0.000	0.000	0.000	0.000	0.000
128	Zinc	0.031	0.038	0.068	0.168	0.155
	Aluminum	NA	NA	NA	NA	NA
	Iron	2.025	3.598	1.926	7.393	8.541
	Manganese	NA	NA	NA	NA	NA
	Phenols, Total	0.008	0.005	0.029	0.034	0.020
	Strontium	0.000	0.000	0.000	0.000	0.000
	Oil & Grease	0.519	0.500	1.586	2.184	1.095
	Total Suspended Solids	3.115	3.634	0.378	13.44	11.86
	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-12

OPEN FORMATION DEHYDRATED BATTERY WASTE CHARACTERISTICS mg/l

		PLANT D		PLANT G			PLANT H
	Temperature (Deg C)	50.0	48.0	47.0	46.0	47.0	30.0
11	1,1,1-Trichloroethane	NA	*	NA	NA	NA	NA
23	Chloroform	NA	8.0	NA	NA	NA	NA
44	Methylene chloride	NA	0.00	NA	NA	NA	NA
55	Naphthalene	*	*	NA	NA	NA	NA
65	Phenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.077	0.051	NA	NA	NA	NA
67	Butyl benzyl phthalate	0.00	0.00	NA	NA	NA	NA
68	Di-n-butyl phthalate	*	*	NA	NA	NA	NA
69	Di-n-octyl phthalate	0.00	0.00	NA	NA	NA	NA
78	Anthracene	*	*	NA	NA	NA	NA
81	Phenanthrene	*	*	NA	NA	NA	NA
84	Pyrene	0.00	0.00	NA	NA	NA	NA
114	Antimony	0.000	0.000	0.18	0.16	0.18	0.34
115	Arsenic	0.000	0.000	0.0005	0.0005	0.004	0.014
118	Cadmium	0.000	0.009	0.000	0.000	0.000	0.004
119	Chromium, Total	0.047	0.048	0.000	0.000	0.000	0.04
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA
120	Copper	0.046	0.036	0.006	0.005	0.004	0.000
122	Lead	8.59	6.72	2.9	5.3	2.62	3.0
123	Mercury	0.000	0.000	NA	NA	NA	NA
124	Nickel	0.096	0.130	0.000	0.000	0.000	0.08
126	Silver	0.000	0.000	NA	NA	NA	NA
128	Zinc	0.350	0.330	0.5	0.5	0.4	0.06
	Aluminum	NA	NA	0.02	0.02	0.4	0.03
	Iron	0.930	2.210	0.66	0.52	0.58	3.52
	Manganese	NA	NA	0.008	0.10	0.006	0.000
	Phenols, Total	0.016	0.005	NA	NA	NA	NA
	Strontium	0.000	0.000	NA	NA	NA	3.52
	Oil & Grease	5.7	2.4	3.0	0.000	8.0	4.7
	Total Suspended Solids	9.0	0.000	166.0	60.0	271.0	17.0
	pH, Minimum	2.0	2.0	2.0	2.0	2.0	1.5
	pH, Maximum	4.1	5.4	3.0	3.0	3.0	3.0

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-13

OPEN FORMATION DEHYDRATED BATTERY WASTE LOADINGS mg/kg

		PLANT D		PLANT G			PLANT H
	Flow (l/kg)	16.10	11.74	3.1167	5.8707	9.0545	1.59
	Temperature (Deg C)	50.0	48.0	47.0	46.0	47.0	30.0
11	1,1,1-Trichloroethane	0.00	0.00	NA	NA	NA	NA
23	Chloroform	0.00	0.00	NA	NA	NA	NA
44	Methylene chloride	0.00	0.00	NA	NA	NA	NA
55	Naphthalene	0.00	0.00	NA	NA	NA	NA
65	Phenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	1.240	0.599	NA	NA	NA	NA
67	Butyl benzyl phthalate	0.00	0.00	NA	NA	NA	NA
68	Di-n-butyl phthalate	0.00	0.00	NA	NA	NA	NA
69	Di-n-octyl phthalate	0.00	0.00	NA	NA	NA	NA
78	Anthracene	0.00	0.00	NA	NA	NA	NA
81	Phenanthrene	0.00	0.00	NA	NA	NA	NA
84	Pyrene	0.00	0.00	NA	NA	NA	NA
114	Antimony	0.000	0.000	0.56	0.94	1.63	0.541
115	Arsenic	0.000	0.000	0.0016	0.0029	0.0036	0.223
118	Cadmium	0.000	0.106	0.000	0.000	0.000	0.0006
119	Chromium, Total	0.757	0.564	0.000	0.000	0.000	0.064
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA
120	Copper	0.741	0.423	0.019	0.029	0.036	0.000
122	Lead	138.3	78.9	9.04	31.1	23.7	4.77
123	Mercury	0.000	0.000	NA	NA	NA	NA
124	Nickel	1.546	1.526	0.000	0.000	0.000	0.127
126	Silver	0.000	0.000	NA	NA	NA	NA
128	Zinc	5.636	3.875	1.56	2.9	3.6	0.10
	Aluminum	NA	NA	0.06	0.12	3.62	0.048
	Iron	14.98	25.95	2.06	3.05	5.25	5.60
	Manganese	NA	NA	0.025	0.59	0.05	0.000
	Phenols, Total	0.258	0.059	NA	NA	NA	NA
	Strontium	0.000	0.000	NA	NA	NA	NA
	Oil & Grease	91.8	28.18	9.35	0.000	72.4	7.47
	Total Suspended Solids	144.9	0.000	517.0	352.0	2454.0	27.0
	pH, Minimum	2.0	2.0	2.0	2.0	2.0	1.5
	pH, Maximum	4.1	5.4	3.0	3.0	3.0	3.0

NA - Not Analyzed

TABLE V-14

BATTERY WASH - DETERGENT
WASTEWATER CHARACTERISTICS
mg/l

		PLANT D			PLANT G
	Temperature (Deg C)	28.0	28.0	28.0	30.0
11	1,1,1-Trichloroethane	*	*	*	NA
23	Chloroform	*	*	*	NA
44	Methylene chloride	*	*	0.0	NA
55	Naphthalene	*	*	*	NA
65	Phenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.013	0.048	0.042	NA
67	Butyl benzyl phthalate	*	0.00	*	NA
68	Di-n-butyl phthalate	*	0.00	*	NA
69	Di-n-octyl phthalate	*	*	*	NA
78	Anthracene	*	*	*	NA
81	Phenanthrene	*	*	*	NA
84	Pyrene	0.00	0.00	0.00	NA
114	Antimony	0.000	0.190	0.180	9.1
115	Arsenic	0.000	0.000	0.130	0.000
118	Cadmium	0.000	0.004	0.000	0.000
119	Chromium, Total	1.160	1.450	3.670	2.2
	Chromium, Hexavalent	NA	NA	NA	NA
120	Copper	0.290	1.470	2.790	63.5
122	Lead	8.42	9.69	18.90	260.0
123	Mercury	0.000	0.000	0.000	NA
124	Nickel	0.630	0.910	2.800	2.0
126	Silver	0.000	0.000	0.0030	NA
128	Zinc	0.810	1.770	7.60	92.4
	Aluminum	NA	NA	NA	12.0
	Iron	26.80	40.00	83.0	728.0
	Manganese	NA	NA	NA	4.0
	Phenols, Total	0.018	0.021	0.023	NA
	Strontium	0.000	0.000	0.000	NA
	Oil & Grease	14.0	10.4	15.0	0.000
	Total Suspended Solids	160.0	70.4	93.0	9050.0
	pH, Minimum	2.0	2.0	2.0	NA
	pH, Maximum	12.0	12.0	12.0	12.0

NA - Not Analyzed
* - ≤ 0.01

TABLE V-15

BATTERY WASH - DETERGENT
WASTE LOADINGS
mg/kg

		PLANT D			PLANT G
	Flow (l/kg)	0.730	0.600	0.500	0.2808
	Temperature (Deg C)	28.0	28.0	28.0	30.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	NA
23	Chloroform	0.00	0.00	0.00	NA
44	Methylene chloride	0.00	0.00	0.00	NA
55	Naphthalene	0.00	0.00	0.00	NA
65	Phenol	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.009	0.029	0.021	NA
67	Butyl benzyl phthalate	0.00	0.00	0.00	NA
68	Di-n-butyl phthalate	0.00	0.00	0.00	NA
69	Di-n-octyl phthalate	0.00	0.00	0.00	NA
78	Anthracene	0.00	0.00	0.00	NA
81	Phenanthrene	0.00	0.00	0.00	NA
84	Pyrene	0.00	0.00	0.00	NA
114	Antimony	0.000	0.114	0.090	2.56
115	Arsenic	0.000	0.000	0.065	0.000
118	Cadmium	0.000	0.004	0.000	0.000
119	Chromium, Total	0.847	0.870	1.835	0.62
	Chromium, Hexavalent	NA	NA	NA	NA
120	Copper	0.212	0.882	1.395	17.8
122	Lead	6.15	5.814	9.45	73.0
123	Mercury	0.000	0.000	0.000	NA
124	Nickel	0.460	0.546	1.400	0.56
126	Silver	0.000	0.000	0.005	NA
128	Zinc	0.591	1.062	3.800	25.9
	Aluminum	NA	NA	NA	3.37
	Iron	19.56	24.00	41.50	204.0
	Manganese	NA	NA	NA	1.123
	Phenols, Total	0.013	0.013	0.011	NA
	Strontium	0.000	0.000	0.000	NA
	Oil & Grease	10.22	6.24	7.50	0.000
	Total Suspended Solids	116.8	42.00	46.50	2541.0
	pH, Minimum	2.0	2.0	2.0	NA
	pH, Maximum	12.0	12.0	12.0	12.0

NA - Not Analyzed

TABLE V-16

BATTERY WASH - WATER ONLY
WASTEWATER CHARACTERISTICS
mg/l

		PLANT A			PLANT F
	Temperature (Deg C)	18.0	18.0	18.0	22.0
11	1,1,1-Trichloroethane	*	*	*	NA
23	Chloroform	*	0.00	0.00	NA
44	Methylene chloride	0.00	0.00	0.00	NA
55	Naphthalene	0.012	0.025	0.037	NA
65	Phenol	NA	0.00	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	*	0.017	NA
67	Butyl benzyl phthalate	*	0.00	*	NA
68	Di-n-butyl phthalate	*	*	*	NA
69	Di-n-octyl phthalate	0.00	*	*	NA
78	Anthracene	*	*	*	NA
81	Phenanthrene	*	*	*	NA
84	Pyrene	0.00	0.00	0.00	NA
114	Antimony	0.000	0.000	0.000	0.061
115	Arsenic	0.000	0.000	0.000	0.010
118	Cadmium	0.002	0.000	0.004	0.000
119	Chromium, Total	0.072	0.000	0.017	0.26
	Chromium, Hexavalent	0.000	0.000	0.000	NA
120	Copper	0.570	0.280	0.330	0.11
122	Lead	6.39	1.200	1.370	0.99
123	Mercury	0.000	0.0090	0.0650	NA
124	Nickel	0.055	0.000	0.007	0.18
126	Silver	0.000	0.000	0.000	NA
128	Zinc	0.240	0.130	0.160	2.0
	Aluminum	NA	NA	NA	0.17
	Iron	6.93	3.900	5.000	11.0
	Manganese	NA	NA	NA	0.085
	Phenols, Total	0.016	0.014	0.022	NA
	Strontium	0.039	0.000	0.000	NA
	Oil & Grease	18.0	23.0	17.0	0.000
	Total Suspended Solids	120.0	19.0	29.0	0.000
	pH, Minimum	2.0	2.0	2.0	1.0
	pH, Maximum	7.7	6.8	5.7	4.0

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-17

BATTERY WASH - WATER ONLY
WASTE LOADINGS
mg/kg

		PLANT A			PLANT F
	Flow (l/kg)	0.651	0.639	0.280	0.185
	Temperature (Deg C)	18.00	18.00	18.00	22.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	NA
23	Chloroform	0.00	0.00	0.00	NA
44	Methylene chloride	0.00	0.00	0.00	NA
55	Naphthalene	0.008	0.016	0.010	NA
65	Phenol	NA	0.00	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.005	NA
67	Butyl benzyl phthalate	0.00	0.00	0.00	NA
68	Di-n-butyl phthalate	0.00	0.00	0.00	NA
69	Di-n-octyl phthalate	0.00	0.00	0.00	NA
78	Anthracene	0.00	0.00	0.00	NA
81	Phenanthrene	0.00	0.00	0.00	NA
84	Pyrene	0.00	0.00	0.00	NA
114	Antimony	0.000	0.000	0.000	0.011
115	Arsenic	0.000	0.000	0.000	0.002
118	Cadmium	0.001	0.000	0.001	0.000
119	Chromium, Total	0.047	0.000	0.005	0.048
	Chromium, Hexavalent	0.000	0.000	0.000	NA
120	Copper	0.371	0.179	0.093	0.020
122	Lead	4.159	0.767	0.384	0.18
123	Mercury	0.000	0.0056	0.0182	NA
124	Nickel	0.036	0.000	0.002	0.033
126	Silver	0.000	0.000	0.000	NA
128	Zinc	0.156	0.083	0.045	0.37
	Aluminum	NA	NA	NA	0.031
	Iron	4.511	2.491	1.402	2.0
	Manganese	NA	NA	NA	0.016
	Phenols, Total	0.010	0.009	0.006	NA
	Strontium	0.025	0.000	0.000	NA
	Oil & Grease	11.72	14.70	4.760	0.000
	Total Suspended Solids	78.12	12.14	8.13	0.000
	pH, Minimum	2.0	2.0	2.0	1.0
	pH, Maximum	7.7	6.8	5.7	4.0

NA - Not Analyzed

TABLE V-18

FLOOR WASH
WASTEWATER CHARACTERISTICS
mg/l

		PLANT A			PLANT F		PLANT H
	Temperature (Deg C)	NA	22.0	NA	25.0	23.0	30.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	NA	NA	NA
23	Chloroform	0.00	0.00	0.00	NA	NA	NA
44	Methylene chloride	*	*	0.00	NA	NA	NA
55	Naphthalene	*	*	*	NA	NA	NA
65	Phenol	NA	0.00	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	*	*	NA	NA	NA
67	Butyl benzyl phthalate	*	*	*	NA	NA	NA
68	Di-n-butyl phthalate	*	*	*	NA	NA	NA
69	Di-n-octyl phthalate	*	0.00	0.00	NA	NA	NA
78	Anthracene	*	*	*	NA	NA	NA
81	Phenanthrene	*	*	*	NA	NA	NA
84	Pyrene	*	0.00	*	NA	NA	NA
114	Antimony	0.940	0.000	0.000	0.28	0.32	0.98
115	Arsenic	0.000	0.000	0.000	0.10	0.19	0.08
118	Cadmium	0.042	0.035	0.011	0.12	0.13	0.04
119	Chromium, Total	0.034	0.019	0.018	1.62	1.86	0.1
	Chromium, Hexavalent	0.000	0.000	0.000	NA	NA	NA
120	Copper	0.290	0.210	0.320	1.27	1.31	0.4
122	Lead	251.0	107.0	51.0	129.0	629.0	120.0
123	Mercury	0.000	0.000	0.000	NA	NA	NA
124	Nickel	0.033	0.023	0.000	1.19	1.21	0.000
126	Silver	0.000	0.000	0.000	NA	NA	NA
128	Zinc	0.940	0.710	0.470	3.46	6.35	15.2
	Aluminum	NA	NA	NA	11.85	18.74	3.9
	Iron	9.76	6.82	6.45	57.0	89.0	12.4
	Manganese	NA	NA	NA	0.57	0.87	0.15
	Phenols, Total	0.153	0.090	0.161	NA	NA	NA
	Strontium	0.000	0.000	0.000	NA	NA	NA
	Oil & Grease	NA	25.0	28.0	4.5	0.000	42.0
	Total Suspended Solids	NA	1116.0	952.0	318.0	545.0	450.0
	pH, Minimum	NA	NA	NA	3.0	3.0	NA
	pH, Maximum	NA	10.2	10.2	8.82	9.0	9.0

NA - Not Analyzed
* - ≤ 0.01

TABLE V-19

FLOOR WASH
WASTE LOADINGS
mg/kg

		PLANT A			PLANT F		PLANT H
	Flow (l/kg)	0.026	0.020	0.026	0.025	0.033	0.0148
	Temperature (Deg C)	NA	22.0	NA	25.0	23.0	30.0
11	1,1,1-Trichloroethane	0.00	0.00	0.00	NA	NA	NA
23	Chloroform	0.00	0.00	0.00	NA	NA	NA
44	Methylene chloride	0.00	0.00	0.00	NA	NA	NA
55	Naphthalene	0.00	0.00	0.00	NA	NA	NA
65	Phenol	NA	0.00	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.00	NA	NA	NA
67	Butyl benzyl phthalate	0.00	0.00	0.00	NA	NA	NA
68	Di-n-butyl phthalate	0.00	0.00	0.00	NA	NA	NA
69	Di-n-octyl phthalate	0.00	0.00	0.00	NA	NA	NA
78	Anthracene	0.00	0.00	0.00	NA	NA	NA
81	Phenanthrene	0.00	0.00	0.00	NA	NA	NA
84	Pyrene	0.00	0.00	0.00	NA	NA	NA
114	Antimony	0.025	0.000	0.000	0.0069	0.0105	0.015
115	Arsenic	0.000	0.000	0.000	0.0026	0.0063	0.001
118	Cadmium	0.001	0.001	0.000	0.0030	0.0044	0.0006
119	Chromium, Total	0.001	0.000	0.000	0.041	0.062	0.002
	Chromium, Hexavalent	0.000	0.000	0.000	NA	NA	NA
120	Copper	0.008	0.004	0.008	0.0318	0.044	0.006
122	Lead	6.62	2.162	1.319	3.235	20.9	1.78
123	Mercury	0.000	0.000	0.000	NA	NA	NA
124	Nickel	0.001	0.000	0.000	0.030	0.040	0.000
126	Silver	0.000	0.000	0.000	NA	NA	NA
128	Zinc	0.025	0.014	0.012	0.086	0.211	0.225
	Aluminum	NA	NA	NA	0.30	0.62	0.058
	Iron	0.257	0.138	0.169	1.416	2.98	0.184
	Manganese	NA	NA	NA	0.014	0.029	0.002
	Phenols, Total	0.004	0.002	0.004	NA	NA	NA
	Strontium	0.000	0.000	0.000	NA	NA	NA
	Oil & Grease	NA	0.505	0.724	0.11	0.000	0.621
	Total Suspended Solids	NA	22.55	24.62	7.96	18.2	6.66
	pH, Minimum	NA	NA	NA	3.0	3.0	NA
	pH, Maximum	NA	10.2	10.2	8.82	9.0	9.0

NA - Not Analyzed
* - ≤ 0.01

TABLE V-20

WET AIR POLLUTION CONTROL WASTEWATER CHARACTERISTICS
mg/l

		PLANT F	PLANT H
	Temperature (Deg C)	22.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.28	0.05
115	Arsenic	0.013	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.06	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.10	0.05
122	Lead	0.4	0.05
123	Mercury	NA	NA
124	Nickel	0.08	0.000
126	Silver	NA	NA
128	Zinc	1.0	0.000
	Aluminum	0.000	0.9
	Iron	13.0	0.000
	Manganese	0.000	0.08
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	6.0	3.4
	Total Suspended Solids	16.0	17.0
	pH, Minimum	1.0	NA
	pH, Maximum	3.5	2.0

NA - Not Analyzed

TABLE V-21

WET AIR POLLUTION CONTROL
WASTE LOADINGS
mg/kg

		PLANT F	PLANT H
	Flow (l/kg)	0.0757	0.142
	Temperature (Deg C)	22.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.021	0.007
115	Arsenic	0.001	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.005	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.008	0.007
122	Lead	0.03	0.007
123	Mercury	NA	NA
124	Nickel	0.006	0.000
126	Silver	NA	NA
128	Zinc	0.08	0.000
	Aluminum	0.000	0.13
	Iron	0.98	0.000
	Manganese	0.000	0.011
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.45	0.48
	Total Suspended Solids	1.2	2.4
	pH, Minimum	1.0	NA
	pH, Maximum	3.5	2.0

NA - Not Analyzed

TABLE V-22

BATTERY REPAIR
WASTEWATER CHARACTERISTICS
mg/l

		PLANT A			PLANT D	
	Temperature (Deg C)	NA	NA	NA	32.0	31.0
11	1,1,1-Trichloroethane	*	*	*	*	*
23	Chloroform	*	0.00	0.00	*	*
44	Methylene chloride	*	0.00	0.00	0.00	*
55	Naphthalene	NA	*	*	*	*
65	Phenol	NA	0.00	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	0.010	0.014	0.013	0.011
67	Butyl benzyl phthalate	NA	*	*	0.00	*
68	Di-n-butyl phthalate	NA	0.012	0.014	*	*
69	Di-n-octyl phthalate	NA	0.00	0.00	*	*
78	Anthracene	NA	*	*	*	*
81	Phenanthrene	NA	*	*	*	*
84	Pyrene	NA	*	*	0.00	0.00
114	Antimony	0.640	0.000	0.000	0.000	0.000
115	Arsenic	0.110	0.000	0.000	0.150	0.000
118	Cadmium	0.220	0.340	0.008	0.013	0.000
119	Chromium, Total	0.250	0.100	0.013	0.250	0.120
	Chromium, Hexavalent	0.000	0.000	0.000	NA	NA
120	Copper	5.460	9.83	0.280	1.220	0.250
122	Lead	65.00	0.540	0.270	1.020	0.830
123	Mercury	0.0060	0.0100	0.0060	0.000	0.000
124	Nickel	0.430	0.520	0.007	0.130	0.170
126	Silver	0.0130	0.000	0.000	0.000	0.000
128	Zinc	8.97	7.510	4.210	1.410	0.500
	Aluminum	NA	NA	NA	NA	NA
	Iron	460.0	370.0	8.05	5.940	2.310
	Manganese	NA	NA	NA	NA	NA
	Phenols, Total	0.039	0.174	0.130	0.011	0.091
	Strontium	0.000	0.000	0.000	0.000	0.000
	Oil & Grease	62.0	46.0	54.0	6.0	9.3
	Total Suspended Solids	624.0	362.0	572.0	1.3	12.0
	pH, Minimum	2.3	NA	NA	2.9	3.4
	pH, Maximum	2.3	2.0	NA	3.9	5.6

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-23

BATTERY REPAIR
WASTE LOADINGS
mg/kg

		PLANT A			PLANT D	
	Flow (l/kg)	0.003	0.004	0.004	0.170	0.321
	Temperature (Deg C)	NA	NA	NA	NA	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
44	Methylene chloride	0.00	0.00	0.00	0.00	0.00
55	Naphthalene	NA	0.00	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	0.00	0.00	0.002	0.004
67	Butyl benzyl phthalate	NA	0.00	0.00	0.00	0.00
68	Di-n-butyl phthalate	NA	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	NA	0.00	0.00	0.00	0.00
78	Anthracene	NA	0.00	0.00	0.00	0.00
81	Phenanthrene	NA	0.00	0.00	0.00	0.00
84	Pyrene	NA	0.00	0.00	0.00	0.00
114	Antimony	0.002	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.025	0.000
118	Cadmium	0.001	0.001	0.000	0.002	0.000
119	Chromium, Total	0.001	0.000	0.000	0.042	0.039
	Chromium, Hexavalent	0.000	0.000	0.000	NA	NA
120	Copper	0.0008	0.038	0.001	0.207	0.080
122	Lead	0.218	0.002	0.001	0.173	0.266
123	Mercury	0.000	0.000	0.000	0.000	0.000
124	Nickel	0.001	0.002	0.000	0.022	0.055
126	Silver	0.000	0.000	0.000	0.000	0.000
128	Zinc	0.033	0.029	0.016	0.239	0.161
	Aluminum	NA	NA	NA	NA	NA
	Iron	1.545	1.438	0.030	1.007	0.742
	Manganese	NA	NA	NA	NA	NA
	Phenols, Total	0.000	0.001	0.000	0.002	0.029
	Strontium	0.000	0.000	0.000	0.000	0.000
	Oil & Grease	0.208	0.179	0.204	1.017	2.986
	Total Suspended Solids	2.096	1.407	2.157	0.220	3.853
	pH, Minimum	2.3	NA	NA	2.9	3.4
	pH, Maximum	2.3	2.0	NA	3.9	5.6

NA - Not Analyzed

TABLE V-24

TRUCK WASH
WASTEWATER CHARACTERISTICS
mg/l

		PLANT G	PLANT H
	Temperature (Deg C)	16.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.31	0.810
115	Arsenic	0.05	0.060
118	Cadmium	0.04	0.24
119	Chromium, Total	0.18	0.14
	Chromium, Hexavalent	NA	NA
120	Copper	1.2	0.8
122	Lead	20.9	63.4
123	Mercury	NA	NA
124	Nickel	0.25	0.15
126	Silver	NA	NA
128	Zinc	1.58	6.12
	Aluminum	37.8	160
	Iron	1050.0	53.8
	Manganese	7.2	1.15
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	7.0	26.0
	Total Suspended Solids	2500.0	1080.0
	pH, Minimum	NA	NA
	pH, Maximum	3.0	4.0

NA - Not Analyzed

TABLE V-25

TRUCK WASH
WASTE LOADINGS
mg/kg

		PLANT G	PLANT H
	Flow (l/kg)	0.0027	0.026
	Temperature (Deg C)	16.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.0008	0.021
115	Arsenic	0.0001	0.0016
118	Cadmium	0.0001	0.006
119	Chromium, Total	0.0005	0.0036
	Chromium, Hexavalent	NA	NA
120	Copper	0.003	0.02
122	Lead	0.056	1.65
123	Mercury	NA	NA
124	Nickel	0.0007	0.0039
126	Silver	NA	NA
128	Zinc	0.004	0.159
	Aluminum	0.102	4.16
	Iron	2.835	1.40
	Manganese	0.019	0.030
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.019	0.68
	Total Suspended Solids	6.75	28.1
	pH, Minimum	NA	NA
	pH, Maximum	3.0	4.0

NA - Not Analyzed

TABLE V-26

HANDWASH
WASTEWATER CHARACTERISTICS
mg/l

		PLANT G	PLANT H
	Temperature (Deg C)	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.42	0.04
115	Arsenic	0.03	0.03
118	Cadmium	0.000	0.000
119	Chromium, Total	0.02	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	1.05	0.7
122	Lead	8.6	13.9
123	Mercury	NA	NA
124	Nickel	0.000	0.05
126	Silver	NA	NA
128	Zinc	1.3	0.36
	Aluminum	0.30	0.10
	Iron	1.45	0.65
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.000	330.0
	Total Suspended Solids	490.0	8.0
	pH, Minimum	NA	NA
	pH, Maximum	8.0	8.0

NA - Not Analyzed

TABLE V-27

HANDWASH
WASTE LOADINGS
mg/kg

		PLANT G	PLANT H
	Flow (l/kg)	0.0256	0.0159
	Temperature (Deg C)	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.011	0.0006
115	Arsenic	0.0008	0.0005
118	Cadmium	0.000	0.000
119	Chromium, Total	0.0005	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.027	0.01
122	Lead	0.22	0.221
123	Mercury	NA	NA
124	Nickel	0.000	0.0008
126	Silver	NA	NA
128	Zinc	0.0331	0.0057
	Aluminum	0.008	0.002
	Iron	0.037	0.010
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.000	5.25
	Total Suspended Solids	12.5	0.76
	pH, Minimum	NA	NA
	pH, Maximum	8.0	8.0

NA - Not Analyzed

TABLE V-28

RESPIRATOR WASH
WASTEWATER CHARACTERISTICS
mg/l

		PLANT G	PLANT H
	Temperature (Deg C)	55.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.0004	0.000
115	Arsenic	0.0002	0.000
118	Cadmium	0.0003	0.000
119	Chromium, Total	0.000	0.62
	Chromium, Hexavalent	NA	NA
120	Copper	0.3	0.5
122	Lead	0.33	5.9
123	Mercury	NA	NA
124	Nickel	0.0	0.4
126	Silver	NA	NA
128	Zinc	0.31	0.52
	Aluminum	0.000	0.000
	Iron	0.003	0.35
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	6.2	5.0
	Total Suspended Solids	7.1	14.0
	pH, Minimum	NA	NA
	pH, Maximum	7.0	7.0

NA - Not Analyzed

TABLE V-29

RESPIRATOR WASH WASTE LOADINGS

mg/kg

		PLANT G	PLANT H
	Flow (l/kg)	0.0063	0.0269
	Temperature (Deg C)	55.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.000	0.000
115	Arsenic	0.000	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.017
	Chromium, Hexavalent	NA	NA
120	Copper	0.002	0.014
122	Lead	0.0021	0.16
123	Mercury	NA	NA
124	Nickel	0.000	0.01
126	Silver	NA	NA
128	Zinc	0.002	0.014
	Aluminum	0.000	0.000
	Iron	0.000	0.009
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.039	0.13
	Total Suspended Solids	0.045	0.38
	pH, Minimum	NA	NA
	pH, Maximum	7.0	7.0

NA - Not Analyzed

TABLE V-30

LAUNDRY
WASTEWATER CHARACTERISTICS
mg/1

		PLANT G	PLANT H
	Temperature (Deg C)	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.15	0.06
115	Arsenic	0.02	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.2	0.25
122	Lead	14.9	11.5
123	Mercury	NA	NA
124	Nickel	0.000	0.000
126	Silver	NA	NA
128	Zinc	1.06	0.1
	Aluminum	0.30	0.20
	Iron	1.35	0.55
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	90.0	8.4
	Total Suspended Solids	110.0	160.0
	pH, Minimum	NA	NA
	pH, Maximum	6.0	6.0

NA - Not Analyzed

TABLE V-31

LAUNDRY
WASTE LOADINGS
mg/kg

		PLANT G	PLANT H
	Flow (l/kg)	0.0850	0.0919
	Temperature (Deg C)	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.013	0.0055
115	Arsenic	0.002	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.017	0.023
122	Lead	1.27	1.057
123	Mercury	NA	NA
124	Nickel	0.000	0.000
126	Silver	NA	NA
128	Zinc	0.090	0.009
	Aluminum	0.026	0.018
	Iron	0.115	0.051
	Manganese	0.000	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	7.65	0.77
	Total Suspended Solids	9.35	14.7
	pH, Minimum	NA	NA
	pH, Maximum	6.0	6.0

NA - Not Analyzed

TABLE V-32

REPORTED TOTAL PROCESS FLOW

Plant Number	Reported Flow Rate (l/hr)	Plant Number	Reported Flow Rate (l/hr)	Plant Number	Reported Flow Rate (l/hr)
107	1503	288	NA	466	0
110	NA	295	0	467	0
112	3180	299	0	469	15
122	11706	311	20895	472	0
132	NA	320	34450	480	30610
133	NA	321	0	486	NA
135	0	331	2498	491	NA
138	NA	342	61920	493	NA
144	0	346	0	494	3110
146	6815	349	7845	495	0
147	0	350	NA	501	12624
152	9280	356	0	503	0
155	NA	358	7041	504	0
158	0	361	NA	513	1363
170	0	366	0	517	0
173	0	370	NA	520	4542
178	0	371	3390	521	0
179	7.57	372	0	522	0
182	NA	374	3861	526	18170
184	0	377	0	529	570
190	0	382	1197	536	NA
191	37325	386	7950	543	0
198	10266	387	2006	549	47470
207	18851	400	3835	553	3449
208	NA	402	NA	572	2275
212	7041	403	NA	575	3634
213	454	406	NA	594	0
226	9312	421	0	620	NA
233	9375	429	0	623	NA
237	11129	430	0	634	1590
239	6106	436	0	635	1685
242	NA	439	29000	640	25196
255	NA	444	0	646	476
261	2271	446	2063	652	12705
269	12212	448	14645	656	NA
277	NA	450	27252	668	0
278	5770	462	2574	672	52950
280	NA	463	NA	677	0

TABLE V-32 (Continued)

REPORTED TOTAL PROCESS FLOW

Plant Number	Reported Flow Rate (l/hr)	Plant Number	Reported Flow Rate (l/hr)	Plant Number	Reported Flow Rate (l/hr)
680	1534	765	11690	877	46165
681	4542	768	7881	880	0
682	6814	771	1363	883	0
683	0	772	11500	893	2470
685	6359	775	4088	901	0
686	8404	777	4325	917	18851
690	0	781	NA	920	NA
704	27125	785	41660	927	0
705	3180	786	5120	936	3706
706	0	790	0	939	NA
708	NA	796	0	942	0
714	1590	811	NA	943	17261
716	NA	814	13130	947	18397
717	6490	815	598	951	1135
721	0	817	0	963	0
722	NA	820	3407	964	0
725	0	828	40	968	0
730	443	832	10520	971	0
731	2858	844	NA	972	23837
732	3607	852	16070	976	26801
733	NA	854	0	978	1840
738	29080	857	0	982	10540
740	NA	863	11055	979	0
746	0	866	0	990	3180

TABLE V-33

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
107	pH adjust, settling	I
110	None	I
112	pH adjust	I (C)
122	pH adjustment, settling, lagooning	D
132	None	I
133	None indicated	U
135	None	Zero
138	pH adjust	I
144	pH adjust, clarification, sand filtration	Zero
146	Settling, pH adjust, settling	I
147	Evaporation	Zero
152	pH adjust	I
155	None indicated	U
158	None	Zero
170	None	Zero
173	None indicated	Zero
178	pH adjust, clarification, lagooning	Zero
179	None	I
182	None	U
184	None	Zero
190	None	Zero
191	pH adjust	I (C)
198	pH adjust	D (C)
207	pH adjust	I (C)
208	pH adjust	I
212	pH adjust, clarification	I (C)
213	None	I
226	pH adjust	I (C)
233	pH adjust	I
237	pH adjust, settling	I
239	pH adjust, settling	I

TABLE V-33 (Continued)

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
242	None indicated	U
255	None indicated	U
261	pH adjust	I (C)
269	pH adjust	I
277	pH adjust, clarification	I
278	pH adjust	I
280	None indicated	U
288	None indicated	U
295	None indicated	Zero
299	None	Zero
311	pH adjust	I
320	pH adjust	I
321	None	Zero
331	pH adjust	I
342	pH adjust, lagooning	I
346	None	Zero
349	pH adjust, settle, filtration	I
350	None indicated	U
356	None indicated	Zero
358	pH adjust, settle	I
361	None	I
366	None	Zero
370	None indicated	I
371	Clarification, filtration	I
372	None	Zero
374	pH adjust, filtration	I
377	None	Zero
382	pH adjust, clarification, sand filtration	I
386	pH adjust, settling	D (C)
387	pH adjust, filtration	I
400	pH adjust, settling	I

TABLE V-33 (Continued)

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
402	None indicated	U
403	None indicated	U
406	None indicated	U
421	None	Zero
429	None	Zero
430	None	Zero
436	Lagooning, sand filtration	Zero (C)
439	pH adjust, clarification, lagooning	D
444	None	Zero
446	pH adjust, coagulant addition, clarification, filtration	I
448	pH adjust	I
450	pH adjust, filtration	D
462	pH adjust, settling, filtration	I
463	None	I
466	Settling	Zero
467	None	Zero
469	pH adjust, settling	I
472	Settling, pH adjust, clarification	Zero
480	pH adjust, pressure filtration	I
486	None	I
491	None indicated	U
493	None	D
494	pH adjust	I
495	None	Zero
501	pH adjust	I
503	pH adjust, coagulant addition, clarification	Zero
504	None	Zero
513	pH adjust, clarification	I
517	None	Zero
520	pH adjust, coagulant addition, settling, filtration	D (C)

TABLE V-33 (Continued)

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
521	None	Zero
522	None	Zero
526	pH adjust, settling	I
529	pH adjust, settling	I (C)
536	None indicated	U
543	None	Zero
549	pH adjust, clarification, filtration	I
553	pH adjust	I
572	pH adjust, settling	I
575	pH adjust, settling	I
594	None	Zero
620	None indicated	U
623	None	I
634	pH adjust, filtration	I
635	pH adjust, filtration	I
640	pH adjust	I (C)
646	pH adjust, coagulant addition, clarification	I
652	pH adjust	I
656	None indicated	U
668	None	Zero
672	pH adjust, clarification	D
677	None	Zero
680	pH adjust	I
681	pH adjust, filtration	I
682	pH adjust, settling	I (C)
683	pH adjust	Zero
685	pH adjust, settling	I
686	pH adjust, settle	I
690	Settling, atmospheric evaporation	Zero
704	pH adjust	I
705	pH adjust, settling	I

TABLE V-33 (Continued)

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
706	pH adjust, settling	Zero
708	pH adjust, settling	I
714	pH adjust, settling	I
716	Settling	I
717	pH adjust, skimming, clarification	I
721	pH adjust, aeration, atmospheric evaporation	Zero
722	None	U
725	None	Zero
730	pH adjust, settling	D
731	pH adjust	I
732	pH adjust	I
733	pH adjust	I
738	pH adjust	I
740	None indicated	U
746	None	Zero
765	pH adjust, clarification	I
768	pH adjust, settle	I
771	pH adjust, settling and filtration	D
772	pH adjust, coagulant addition, clarification, sand filtration	I
775	pH adjust, clarification	D (C)
777	pH adjust, flocculant addition, flotation	I
781	pH adjust	I
785	pH adjust, clarification	I
786	pH adjust, flotation	I
790	None	Zero
796	None	Zero
811	Unknown	U
814	pH adjust	I
815	Zero	I
817	pH adjust, settling	Zero

TABLE V-33 (Continued)

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
820	pH adjust	I (C)
828	None	I
832	pH adjust	I
844	pH adjust, settling	I
852	pH adjust, flocculant addition, clarification, settling	I
854	None	Zero
857	None	Zero
863	pH adjust, clarification	I
866	None	Zero
877	pH adjust, clarification, filtration	I
880	None	Zero
883	Settling	Zero
893	pH adjust	I
901	Settling	Zero
917	pH adjust	I
920	None	I
927	None	Zero
936	pH adjust, settle	I
939	None	U
942	None	Zero
943	pH adjust, filtration	D
947	pH adjust, filtration	I (C)
951	Clarification	I (C)
963	None	Zero
964	None	Zero
968	None	Zero
971	Settling, filtration	Zero
972	pH adjust, settling	I
976	pH adjust	I
978	pH adjust, flocculant addition, clarification	I

TABLE V-33 (Continued)

TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Plant ID	Treatment In-Place	Discharge[1/]
979	None	Zero
982	pH adjust, settling	I (C)
990	pH adjust	I (C)

1/ I = Indirect
D = Direct
U = Unknown
C = Closed

TABLE V-34

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	*	*	*	0.025	*	*
23	Chloroform	*	*	0.00	*	0.00	0.00
44	Methylene chloride	*	*	0.00	*	*	0.00
55	Naphthalene	0.006	0.013	0.015	*	*	*
65	Phenol	NA	0.00	NA	*	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	*	0.008	0.135	0.044	0.030
67	Butyl benzyl phthalate	*	*	*	0.017	0.00	0.00
68	Di-n-butyl phthalate	*	0.00	0.00	*	0.00	0.00
69	Di-n-octyl phthalate	0.00	*	*	0.140	0.00	0.00
78	Anthracene	*	*	*	0.032	0.00	0.00
81	Phenanthrene	*	*	*	0.032	0.00	0.00
84	Pyrene	0.00	*	*	*	0.00	*
114	Antimony	0.002	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.005	0.000	0.000	0.000
118	Cadmium	0.027	0.003	0.005	0.008	0.003	0.012
119	Chromium, Total	0.120	0.032	0.047	0.009	0.012	0.017
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	NA	NA
120	Copper	0.436	0.278	0.378	0.083	0.090	0.110
122	Lead	6.88	1.434	1.170	13.00	15.40	45.90
123	Mercury	0.0000	0.0100	0.0260	NA	0.000	0.000
124	Nickel	0.120	0.022	0.027	0.000	0.000	0.020
126	Silver	0.0000	0.000	0.000	0.0330	0.0070	0.0150
128	Zinc	0.305	0.134	0.193	0.333	0.350	0.380
	Aluminum	NA	NA	NA	NA	NA	NA
	Iron	6.64	6.55	5.522	2.000	3.800	4.370
	Manganese	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.015	0.014	0.050	0.008	0.000	0.000
	Strontium	0.021	0.000	0.000	NA	0.000	0.000
	Oil & Grease	49.0	13.0	9.2	36.5	10.6	5.2
	Total Suspended Solids	416.0	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
* - $\leq$ 0.01

TABLE V-34 (continued)

TOTAL RAW WASTE FOR VISITS
mg/l

		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	*	*	*	*	*	*	*
23	Chloroform	0.00	0.00	0.00	*	*	*	0.00
44	Methylene chloride	0.00	*	*	*	*	0.00	0.00
55	Naphthalene	*	0.00	0.00	0.001	0.001	0.002	0.00
65	Phenol	NA	NA	NA	NA	NA	NA	0.00
66	Bis(2-ethylhexyl)phthalate	*	0.01	*	0.032	0.037	0.050	*
67	Butyl benzyl phthalate	0.00	0.00	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	*	*	*	0.00
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	0.000	0.000	0.000	0.000	0.090	0.194	0.130
115	Arsenic	0.000	0.000	0.000	0.019	0.000	0.116	NA
118	Cadmium	0.000	0.000	0.000	0.002	0.004	0.004	0.034
119	Chromium, Total	0.097	0.057	0.068	0.670	0.732	3.267	NA
120	Copper	0.063	0.078	0.053	0.324	0.772	2.502	NA
122	Lead	1.000	1.360	1.450	18.29	15.64	44.94	13.40
123	Mercury	0.000	0.000	0.000	0.000	0.000	0.000	0.0460
124	Nickel	0.077	0.036	0.069	0.384	0.506	2.493	NA
126	Silver	0.000	0.000	0.000	0.0000	0.0000	0.0230	0.0080
128	Zinc	0.054	0.120	0.190	0.747	1.068	6.80	3.88
	Aluminum	NA	NA	NA	NA	NA	NA	NA
	Iron	9.24	15.51	9.41	15.45	20.14	74.0	390.0
	Manganese	NA	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.000	0.000	0.000	0.018	0.038	0.028	0.020
	Strontium	0.027	0.033	0.033	0.000	0.000	0.003	0.000
	Oil & Grease	3.1	4.0	3.9	10.3	9.4	16.7	3.0
	Total Suspended Solids	6.0	14.0	5.0	350.1	974.0	1300.0	184.0
	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
* - $\leq$ 0.01

TABLE V-34 (Continued)

TOTAL RAW WASTE FOR VISITS
mg/l

		PLANT F	PLANT G			PLANT H		
	Temperature (Deg C)	27.0	38.0	38.0	38.0	30.0	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA
23	Chloroform	NA	NA	NA	NA	NA	NA	NA
44	Methylene chloride	NA	NA	NA	NA	NA	NA	NA
55	Naphthalene	NA	NA	NA	NA	NA	NA	NA
65	Phenol	NA	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA	NA
67	Butyl benzyl phthalate	NA	NA	NA	NA	NA	NA	NA
68	Di-n-butyl phthalate	NA	NA	NA	NA	NA	NA	NA
69	Di-n-octyl phthalate	NA	NA	NA	NA	NA	NA	NA
78	Anthracene	NA	NA	NA	NA	NA	NA	NA
81	Phenanthrene	NA	NA	NA	NA	NA	NA	NA
84	Pyrene	NA	NA	NA	NA	NA	NA	NA
114	Antimony	0.114	0.536	0.415	0.226	0.078	0.054	0.076
115	Arsenic	0.014	0.041	0.030	0.010	0.004	0.004	0.002
118	Cadmium	0.0054	0.008	0.004	0.0001	0.002	0.004	0.001
119	Chromium, Total	0.244	0.090	0.103	0.020	0.047	0.060	0.054
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA	NA
120	Copper	0.155	0.273	0.165	0.122	0.150	0.115	0.074
122	Lead	135.4	36.2	13.5	13.2	23.9	12.5	24.1
123	Mercury	NA	NA	NA	NA	NA	NA	NA
124	Nickel	0.192	0.021	0.055	0.008	0.027	0.036	0.032
126	Silver	NA	NA	NA	NA	NA	NA	NA
128	Zinc	1.398	0.871	0.736	0.616	0.131	0.300	0.211
	Aluminum	1.748	2.80	2.12	0.53	1.61	1.44	1.22
	Iron	12.084	20.1	23.6	6.6	6.60	7.41	4.94
	Manganese	0.1053	0.42	0.34	0.11	0.11	0.11	0.09
	Phenols, Total	NA	NA	NA	NA	NA	NA	NA
	Strontium	NA	NA	NA	NA	NA	NA	NA
	Oil & Grease	6.27	12.6	10.4	6.3	32.5	40.8	4.77
	Total Suspended Solids	57.36	249.0	257.0	70.0	93.9	57.6	40.4
	pH, Minimum	1.7	1.5	2.0	2.0	1.0	1.0	1.0
	pH, Maximum	10.11	8.0	8.0	8.0	8.0	8.0	8.0

NA - Not Analyzed

TABLE V-35

LEAD SUBCATEGORY
TOTAL RAW WASTE LOADINGS
mg/kg

		PLANT A			PLANT B		
	Flow (1/kg)	1.207	1.196	0.705	8.84	9.87	10.27
	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	0.221	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	0.008	0.016	0.011	0.00	0.00	0.00
65	Phenol	NA	0.00	NA	0.00	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.00	0.00	0.006	1.193	0.434	0.308
67	Butyl benzyl phthalate	0.00	0.00	0.00	0.150	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	1.237	0.00	0.00
78	Anthracene	0.00	0.00	0.00	0.283	0.00	0.00
81	Phenanthrene	0.00	0.00	0.00	0.283	0.00	0.00
84	Pyrene	0.00	0.00	0.00	0.00	0.00	0.00
114	Antimony	0.002	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.004	0.000	0.000	0.000
118	Cadmium	0.033	0.004	0.004	0.071	0.030	0.123
119	Chromium, Total	0.145	0.038	0.033	0.080	0.118	0.175
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	NA	NA
120	Copper	0.526	0.333	0.266	0.734	0.889	1.130
122	Lead	8.31	1.715	0.825	114.9	152.0	471.4
123	Mercury	0.0000	0.0120	0.0185	NA	0.000	0.000
124	Nickel	0.145	0.026	0.019	0.000	0.000	0.205
126	Silver	0.0000	0.0000	0.0000	0.2920	0.0690	0.0000
128	Zinc	0.368	0.160	0.136	2.943	3.455	3.903
	Aluminum	NA	NA	NA	NA	NA	NA
	Iron	8.02	7.84	3.894	17.68	37.52	44.88
	Manganese	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.019	0.017	0.035	0.071	0.000	0.000
	Strontium	0.025	0.000	0.000	NA	0.000	0.000
	Oil & Grease	59.15	15.51	6.52	322.6	104.7	53.41
	Total Suspended Solids	502.2	17.97	11.60	510.8	308.0	538.2
	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-35 (Continued)

LEAD SUBCATEGORY
TOTAL RAW WASTE LOADINGS
mg/kg

		PLANT C			PLANT D			PLANT E
	Flow (l/kg)	6.68	6.59	6.98	1.351	1.252	0.562	0.218
	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	0.00	0.066	0.00	0.043	0.046	0.028	0.000
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	0.000	0.000	0.000	0.000	0.113	0.109	0.028
115	Arsenic	0.000	0.000	0.000	0.025	0.000	0.065	NA
118	Cadmium	0.000	0.000	0.000	0.003	0.005	0.002	0.007
119	Chromium, Total	0.648	0.376	0.474	0.905	0.917	1.835	NA
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA	0.000
120	Copper	0.421	0.514	0.370	0.437	0.967	1.405	NA
122	Lead	6.68	8.96	10.12	24.71	19.60	25.24	2.920
123	Mercury	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101
124	Nickel	0.515	0.237	0.481	0.519	0.634	1.400	NA
126	Silver	0.0000	0.0000	0.0000	0.0010	0.0010	0.0129	0.0018
128	Zinc	0.361	0.791	1.326	1.009	1.337	3.821	0.845
	Aluminum	NA	NA	NA	NA	NA	NA	NA
	Iron	61.8	102.2	65.7	20.87	25.21	41.58	85.0
	Manganese	NA	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.000	0.000	0.000	0.025	0.048	0.016	0.004
	Strontium	0.180	0.218	0.230	0.000	0.000	0.001	0.000
	Oil & Grease	20.72	26.37	27.21	13.96	11.82	9.36	0.654
	Total Suspended Solids	40.11	92.28	34.89	472.8	1220.0	731.0	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

TABLE V-35 (Continued)

LEAD SUBCATEGORY
TOTAL RAW WASTE LOADINGS
mg/kg

		PLANT F	PLANT G			PLANT H		
	Flow (l/kg)	0.407	1.02	1.4	2.10	3.36	3.17	7.65
	Temperature (Deg C)	27.0	38.0	38.0	38.0	30.0	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA
23	Chloroform	NA	NA	NA	NA	NA	NA	NA
44	Methylene chloride	NA	NA	NA	NA	NA	NA	NA
55	Naphthalene	NA	NA	NA	NA	NA	NA	NA
65	Phenol	NA	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA	NA
67	Butyl benzyl phthalate	NA	NA	NA	NA	NA	NA	NA
68	Di-n-butyl phthalate	NA	NA	NA	NA	NA	NA	NA
69	Di-n-octyl phthalate	NA	NA	NA	NA	NA	NA	NA
78	Anthracene	NA	NA	NA	NA	NA	NA	NA
81	Phenanthrene	NA	NA	NA	NA	NA	NA	NA
84	Pyrene	NA	NA	NA	NA	NA	NA	NA
114	Antimony	0.0465	0.545	0.582	0.474	0.262	0.172	0.583
115	Arsenic	0.0055	0.042	0.042	0.020	0.012	0.011	0.018
118	Cadmium	0.002	0.008	0.006	0.0002	0.006	0.013	0.010
119	Chromium, Total	0.010	0.091	0.145	0.0425	0.157	0.190	0.410
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA	NA
120	Copper	0.063	0.277	0.232	0.2563	0.504	0.365	0.565
122	Lead	55.16	36.8	18.9	27.7	80.4	39.7	185.0
123	Mercury	NA	NA	NA	NA	NA	NA	NA
124	Nickel	0.078	0.021	0.077	0.016	0.090	0.114	0.247
126	Silver	NA	NA	NA	NA	NA	NA	NA
128	Zinc	0.570	0.885	1.03	1.29	0.439	0.951	1.617
	Aluminum	0.711	2.86	2.97	1.11	5.41	4.56	9.33
	Iron	4.92	20.4	33.0	13.9	22.2	23.5	37.8
	Manganese	0.043	0.43	0.48	0.23	0.37	0.35	0.69
	Phenols, Total	NA	NA	NA	NA	NA	NA	NA
	Strontium	NA	NA	NA	NA	NA	NA	NA
	Oil & Grease	2.55	12.7	14.6	13.3	109.0	129.0	36.5
	Total Suspended Solids	23.37	253.0	360.0	146.0	315.0	183.0	309.3
	pH, Minimum	1.7	1.5	2.0	2.0	1.0	1.0	1.0
	pH, Maximum	10.11	8.0	8.0	8.0	8.0	8.0	8.0

NA - Not Analyzed

TABLE V-36

STATISTICAL ANALYSIS (mg/l) OF THE LEAD SUBCATEGORY TOTAL RAW WASTE CONCENTRATIONS

		Minimum	Maximum	Mean	Median	# Val	# Zeros	# Pts
	Temperature (Deg C)	15.3	38.0	25.4	27.0	19	0	19
11	1,1,1-Trichloroethane	*	0.025	0.002	*	13	0	13
23	Chloroform	0.00	*	*	0.00	6	7	13
44	Methylene chloride	0.00	*	*	*	8	5	13
55	Naphthalene	0.00	0.015	0.003	*	10	3	13
65	Phenol	0.00	*	*	*	1	2	3
66	Bis(2-ethylhexyl)phthalate	*	0.135	0.029	0.030	13	0	13
67	Butyl benzyl phthalate	0.00	0.017	0.001	*	7	6	13
68	Di-n-butyl phthalate	0.00	*	*	*	8	5	13
69	Di-n-octyl phthalate	0.00	0.140	0.011	0.00	6	7	13
78	Anthracene	0.00	0.032	0.002	*	7	6	13
81	Phenanthrene	0.00	0.032	0.002	*	7	6	13
84	Pyrene	0.00	*	*	0.00	5	8	13
114	Antimony	0.000	0.536	0.096	0.028	11	9	20
115	Arsenic	0.000	0.116	0.013	0.002	10	9	19
118	Cadmium	0.000	0.034	0.006	0.004	17	3	20
119	Chromium, Total	0.009	3.267	0.301	0.06	19	0	19
	Chromium, Hexavalent	0.000	0.000	0.000	0.000	0	5	5
120	Copper	0.053	2.502	0.327	0.15	19	0	19
122	Lead	1.0	135.4	21.93	13.45	20	0	20
123	Mercury	0.0000	0.046	0.0068	0.0000	4	8	12
124	Nickel	0.000	2.493	0.217	0.036	17	2	19
126	Silver	0.0000	0.0330	0.0066	0.0000	8	5	13
128	Zinc	0.054	6.8	0.941	0.342	20	0	20
	Aluminum	0.53	2.80	1.638	1.61	7	0	7
	Iron	2.0	390.0	32.2	8.3	20	0	20
	Manganese	0.09	0.42	0.184	0.11	7	0	7
	Phenols, Total	0.000	0.050	0.015	0.014	8	5	13
	Strontium	0.000	0.033	0.010	0.000	5	7	12
	Oil & Grease	3.0	49.0	14.4	9.9	20	0	20
	Total Suspended Solids	5.0	1,300.0	212.4	57.7	20	0	20
	pH, Minimum	1.0	2.2	1.8	2.0	19	0	19
	pH, Maximum	2.4	11.9	7.3	8.0	19	0	19

* - ≤ 0.01

TABLE V-37

STATISTICAL ANALYSIS (mg/kg) OF THE LEAD SUBCATEGORY TOTAL RAW WASTE LOADINGS

		Minimum	Maximum	Mean	Median
	Flow (l/kg)	0.218	10.27	3.74	1.75
	Temperature (Deg C)	15.3	38.0	25.4	27.0
11	1,1,1-Trichloroethane	0.00	0.221	0.017	0.00
23	Chloroform	0.00	0.00	0.00	0.00
44	Methylene chloride	0.00	0.016	0.00	0.00
65	Phenol	0.00	0.00	0.00	0.00
66	Bis(2-ethylhexyl)phthalate	0.00	1.193	0.185	0.043
67	Butyl benzyl phthalate	0.00	0.028	0.012	0.00
68	Di-n-butyl phthalate	0.00	0.00	0.00	0.00
69	Di-n-octyl phthalate	0.00	1.237	0.095	0.00
78	Anthracene	0.00	0.283	0.022	0.00
81	Phenanthrene	0.00	0.283	0.022	0.00
84	Pyrene	0.00	0.00	0.00	0.00
114	Antimony	0.000	0.583	0.146	0.015
115	Arsenic	0.000	0.065	0.013	0.004
118	Cadmium	0.000	0.123	0.016	0.0055
119	Chromium, Total	0.01	1.835	0.357	0.157
	Chromium, Hexavalent	0.000	0.000	0.000	0.000
120	Copper	0.063	1.405	0.540	0.437
122	Lead	0.825	471.4	64.55	24.98
123	Mercury	0.0000	0.0185	0.0034	0.0000
124	Nickel	0.000	1.4	0.2539	0.114
126	Silver	0.000	0.2920	0.0291	0.0000
128	Zinc	0.136	3.903	1.362	0.98
	Aluminum	0.711	9.33	3.850	2.97
	Iron	3.894	102.2	33.89	24.36
	Manganese	0.043	0.69	0.370	0.37
	Phenols, Total	0.000	0.071	0.018	0.016
	Strontium	0.000	0.230	0.055	0.000
	Oil & Grease	0.654	322.6	49.48	18.12
	Total Suspended Solids	11.6	1220.0	305.5	280.5
	pH, Minimum	1.0	2.2	1.8	2.0
	pH, Maximum	2.4	11.9	7.3	8.0

TABLE V-38

EFFLUENT CHARACTERISTICS REPORTED IN DCP BY PLANTS PRACTICING pH ADJUSTMENT AND SETTLING TECHNOLOGY

			Pollutant Parameters (mg/l)						
ID #	Direct/ Indirect	Production Normalized Effluent l/kg	pH	O&G	TSS	Fe	Pb	Zn	Paste Recirc.
A	D	5.10	6.9		20				
B	I	1.88					1.1-4.3		X
C	I	3.15					7.5		
D	D	8.0					0.4		
E	I	4.56	7.5				0.5		
F	I	9.76					1.0		
G	I	2.01	6.9	8.2	3.7		0.8		
H	D	6.35	7	4.5	3		0.187		
I	I	13.32				2.7			X
J	I	51.9	6.65		1.4	0.2	1.0	0.1	X
K	D	1.74			4.6		0.28		
L	I	1.34							X
M	I	2.57					1.0		
N	D	5.76			330		0.25		
O	I	1.58	5.85	26.14	257.7				

TABLE V-39

EFFLUENT CHARACTERISTICS REPORTED IN INDUSTRY SURVEY BY PLANTS PRACTICING pH ADJUSTMENT AND SETTLING TECHNOLOGY

		Pollutant Parameters (mg/l)											
		Influent to WWT				Average Effluent from WWT				Permit or POTW Limit			
ID #	Direct/ Indirect	pH	TSS	Pb	SO_4	pH	TSS	Pb	SO_4	pH	TSS	Pb	SO_4
A	D					8.0		0.47		6-9			
B	I					7.41	4,810	3.36			250	0.4	
C	I									5.5-10	400		
D	I						3.80	2.3		6.0-9.0		10	
E	I	1.66		28.8	2,250	7.93	29	1.51			250	1.0	
F	I	2				8				5.5-10			
G	D	3-11	<100	1-15		7.6	30	0.09		6-9.5		0.5	
H	I	2.0	3,580	18		8		0.5					
I	I	1.5-6.7		8-75				0.76		6.5-8.5		0.6	
J	I	2.1	1,203	450		8.2		2.3		6-10	None	0.05	
K	D	1.25	38	18.5	7,820	8.76	7	0.14		6-9	20	0.14	
L	I	2.61		7.90		7.8	34	0.55		6-9	50	0.5	
M	I	1	100	1-10		9.0	50	1.1		5.5-9.5		3.0	
N	I	1.25-3.5		49-80	6,073		29	3.11		6.5-9.5			
O	I	2				9.0	150	0.5		>6.0		40	
P	I			1-10		9.0		1.1				3.0	
Q	I	3-9	1,500	1-40		8.8-9.2	300-500	3.5		6.0-9.5	None	0.5	
R	I		13,470	1,300			57.1	1.30		6-9.5	None		
S	I					9.2	70.0	6.0		>6.0	None	40.0	
T	I	1.7	81	5.7		7.9	48.3	2.91		6-9	250	5.0	
U	I	2				8		0.1		6-10	250		
V	I	2				7.5	90	0.3		6.5-9			

< - Less Than

> - Greater Than

WWT - Wastewater Treatment

TABLE V-40

EFFLUENT CHARACTERISTICS REPORTED IN DCP BY PLANTS PRACTICING pH ADJUSTMENT AND FILTRATION

ID #	Direct/ Indirect	Production Normalized Effluent l/kg	pH	Pollutant Parameters (mg/l) 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					0.5		
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	

+ - Filter & Settle.

TABLE V-41

EFFLUENT CHARACTERISTICS REPORTED IN INDUSTRY SURVEY BY PLANTS PRACTICING pH ADJUSTMENT AND FILTER TECHNOLOGY

		Pollutant Parameters (mg/l)											
		Influent to WWT				Average Effluent from WWT				Permit or POTW Limit			
ID #	Direct/ Indirect	pH	TSS	Pb	SO_4	pH	TSS	Pb	SO_4	pH	TSS	Pb	SO_4
A	I					7.1		0.9		5-12			
B	I	2.0		10		7.3				6-9			
C	D					7.5		0.3		6-9		0.5	
D	I	2.0		6.9		7.5		1.0		6-9			
E	I	<1.0		5-300		7.5		2.0		6-10		0.07	
F	I	<2.0		7.0		6.92		0.25		6-9		2	
G	I					8.7		0.5	1,850	6-9	265	0.5	750
H	D	1.7		26.4		7.67	29	0.24		6-9	20	0.14	

< - Less Than

WWT - Wastewater Treatment

TABLE V-42

EFFLUENT CHARACTERISTICS REPORTED IN DCP BY PLANTS PRACTICING pH ADJUSTMENT ONLY

ID #	Direct/ Indirect	Production Normalized Effluent 1/kg	Pollutant Parameters (mg/1)						Paste Recirc.
			pH	O&G	TSS	Fe	Pb	Zn	
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					27.5		
F	I	5.35							
G	I	51.9	6.95		1.4	0.2	1.0		X
H	I	10.1			33			0.4	
I	I	5.02	5.7		32		3.95		
J+	I	26.4					10-15		
K	I	63.3				0	3.0		X
L	I	15.0					26.92	0.24	

+ - Reports no effluent treatment prior to release to POTW.

TABLE V-43

EFFLUENT CHARACTERISTICS REPORTED IN INDUSTRY SURVEY BY PLANTS PRACTICING pH ADJUSTMENT ONLY

		Pollutant Parameters (mg/l)											
		Influent to WWT				Average Effluent from WWT				Permit or POTW Limit			
ID #	Direct/ Indirect	pH	TSS	Pb	SO_4	pH	TSS	Pb	SO_4	pH	TSS	Pb	SO_4
A	I					7.2		3.9				15.0	
B	I												
C	I					7.0		3.5		6.0-9.0		None	
D	I	2-10	<100	1-15		7.8	50	1.5		6-9.5		2	
E	I	2-9	50-750	2-20		7.5	25	3.8		6-9.5		1.0	
F	I	1-2	346	6.5		6.5	350	6.0		5-10		1.0	
G	I	2				8				5.5-10			
H	I	2-9	<100	15-100		7	<100	5		5.5-9.5		0.5	
I	I	<2.0				7.5	47	1.25		5-10	275	1.0	
J	I	1-11	50-150	1.0-10.0		8	50	4.0		6-9.5	300	2.0	
K	I	2				6.5	5,200	20.6		5-10			
L	I					8	100	6.0	2,000	5.5-7			
M	I	1-10	200-1,500	7-25		7.8	<300	0.5		6-9.0	350	0.2	
N	I	2-12	<100	2-50		8.4	<75	4.0		6-9.5		0.5	
O	I	2-12	<75	1-15		8	68	2.3		5.5-10		0.3	
P	I					6.6	67	13.2		6-9		40	
Q	I	1-12	<100	2-10		6.5-7.5	<50	3.0		6-9.5	<300		
R	I					8.7		5.6		6-9		None	

< - Less Than

WWT - Wastewater Treatment

TABLE V-44

INFLUENT TO WASTEWATER TREATMENT
POLLUTANT CHARACTERISTICS
mg/l

		PLANT F		PLANT G		
	Temperature (Deg C)	28.0	27.0	28.0	28.0	26.0
11	1,1,1-Trichloroethane	NA	NA	NA	NA	NA
23	Chloroform	NA	NA	NA	NA	NA
44	Methylene chloride	NA	NA	NA	NA	NA
55	Naphthalene	NA	NA	NA	NA	NA
65	Phenol	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA
67	Butyl benzyl phthalate	NA	NA	NA	NA	NA
68	Di-n-butyl phthalate	NA	NA	NA	NA	NA
69	Di-n-octyl phthalate	NA	NA	NA	NA	NA
78	Anthracene	NA	NA	NA	NA	NA
81	Phenanthrene	NA	NA	NA	NA	NA
84	Pyrene	NA	NA	NA	NA	NA
114	Antimony	0.021	0.017	0.26	0.28	0.21
115	Arsenic	0.017	0.006	0.04	0.02	0.01
118	Cadmium	0.009	0.000	0.04	0.000	0.000
119	Chromium, Total	0.66	0.51	0.06	0.08	0.06
	Chromium, Hexavalent	NA	NA	NA	NA	NA
120	Copper	0.2	0.089	0.15	0.1	0.05
122	Lead	4.8	4.3	4.2	14.6	6.6
123	Mercury	NA	NA	NA	NA	NA
124	Nickel	0.47	0.39	0.05	0.05	0.05
126	Silver	NA	NA	NA	NA	NA
128	Zinc	2.8	0.34	0.78	0.76	0.6
	Aluminum	0.87	0.54	2.6	1.6	1.1
	Iron	23.0	18.0	9.8	8.2	5.2
	Manganese	0.000	0.23	0.15	0.15	0.2
	Phenols, Total	NA	NA	NA	NA	NA
	Strontium	NA	NA	NA	NA	NA
	Oil & Grease	0.000	0.000	2.0	18.0	22.0
	Total Suspended Solids	26.0	26.0	270.0	70.0	52.0
	pH, Minimum	1.4	1.3	1.5	1.5	1.5
	pH, Maximum	1.5	1.6	1.5	2.0	1.7

NA - Not Analyzed

TABLE V-44 (Continued)

INFLUENT TO WASTEWATER TREATMENT
POLLUTANT CHARACTERISTICS
mg/l

		PLANT H		
	Temperature (Deg C)	30.0	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA	NA
23	Chloroform	NA	NA	NA
44	Methylene chloride	NA	NA	NA
55	Naphthalene	NA	NA	NA
65	Phenol	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA
67	Butyl benzyl phthalate	NA	NA	NA
68	Di-n-butyl phthalate	NA	NA	NA
69	Di-n-octyl phthalate	NA	NA	NA
78	Anthracene	NA	NA	NA
81	Phenanthrene	NA	NA	NA
84	Pyrene	NA	NA	NA
114	Antimony	2.1	3.6	7.0
115	Arsenic	0.42	0.54	0.94
118	Cadmium	1.8	1.6	2.0
119	Chromium, Total	0.000	0.000	0.000
	Chromium, Hexavalent	NA	NA	NA
120	Copper	0.5	1.0	2.5
122	Lead	25.0	21.0	41.0
123	Mercury	NA	NA	NA
124	Nickel	0.5	0.5	1.5
126	Silver	NA	NA	NA
128	Zinc	3.2	2.6	10.8
	Aluminum	4.0	4.0	8.0
	Iron	21.0	30.5	54.5
	Manganese	1.0	1.0	2.0
	Phenols, Total	NA	NA	NA
	Strontium	NA	NA	NA
	Oil & Grease	2.0	9.4	12.0
	Total Suspended Solids	22.0	95.0	200.0
	pH, Minimum	1.0	1.0	1.0
	pH, Maximum	6.0	1.0	1.0

NA - Not Analyzed

TABLE V-45

EFFLUENT FROM SAMPLED PLANTS

mg/l

		PLANT B			PLANT C		
	Temperature (Deg C)	17.0	17.0	17.0	7.60	7.80	8.50
11	1,1,1-Trichloroethane	*	*	*	*	*	*
23	Chloroform	0.029	0.00	0.00	0.00	0.00	0.00
44	Methylene chloride	*	0.00	0.00	0.00	*	*
55	Naphthalene	0.00	0.00	0.00	0.00	0.00	0.00
65	Phenol	*	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	0.016	*	*	*	*	*
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	0.000	0.000	0.000	0.000	0.000	0.000
115	Arsenic	0.000	0.000	0.000	0.000	0.000	0.000
118	Cadmium	0.003	0.000	0.000	0.000	0.000	0.000
119	Chromium, Total	0.000	0.010	0.005	0.000	0.005	0.005
	Chromium, Hexavalent	0.000	NA	NA	NA	NA	NA
120	Copper	0.000	0.040	0.034	0.018	0.014	0.019
122	Lead	1.350	4.050	3.580	0.110	0.130	0.110
123	Mercury	NA	0.000	0.000	0.000	0.000	0.000
124	Nickel	0.000	0.000	0.012	0.011	0.009	0.011
126	Silver	0.000	0.000	0.000	0.000	0.000	0.000
128	Zinc	0.095	0.096	0.084	0.000	0.000	0.037
	Aluminum	NA	NA	NA	NA	NA	NA
	Iron	0.000	0.710	0.590	0.760	0.920	0.950
	Manganese	NA	NA	NA	NA	NA	NA
	Phenols, Total	0.000	0.000	0.000	0.000	0.000	0.000
	Strontium	NA	0.020	0.013	0.029	0.027	0.027
	Oil & Grease	10.0	9.9	5.0	1.4	2.7	2.2
	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
$*$ - ≤ 0.01

TABLE V-45 (continued)

EFFLUENT FROM SAMPLED PLANTS
mg/l

		PLANT D			PLANT F	
	Temperature (Deg C)	32.0	31.0	NA	28.0	28.0
11	1,1,1-Trichloroethane	*	*	*	NA	NA
23	Chloroform	*	*	*	NA	NA
44	Methylene chloride	*	*	*	NA	NA
55	Naphthalene	0.00	0.00	0.00	NA	NA
65	Phenol	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	*	0.023	0.00	NA	NA
67	Butyl benzyl phthalate	*	0.023	0.00	NA	NA
68	Di-n-butyl phthalate	*	0.00	*	NA	NA
69	Di-n-octyl phthalate	0.00	0.00	0.00	NA	NA
78	Anthracene	*	*	*	NA	NA
81	Phenanthrene	*	*	*	NA	NA
84	Pyrene	0.00	0.00	0.00	NA	NA
114	Antimony	0.000	0.000	0.000	0.044	0.060
115	Arsenic	0.000	0.000	0.000	0.043	0.037
118	Cadmium	0.000	0.000	0.000	0.007	0.003
119	Chromium, Total	0.010	0.010	0.059	0.000	0.000
	Chromium, Hexavalent	NA	NA	NA	NA	NA
120	Copper	0.059	0.050	0.090	0.023	0.012
122	Lead	6.06	3.880	13.30	0.000	0.000
123	Mercury	0.000	0.000	0.000	NA	NA
124	Nickel	0.110	0.068	0.046	0.31	0.35
126	Silver	0.000	0.000	0.000	NA	NA
128	Zinc	0.165	0.000	0.105	0.15	0.000
	Aluminum	NA	NA	NA	0.000	0.000
	Iron	0.420	0.280	3.380	0.000	0.000
	Manganese	NA	NA	NA	0.10	0.13
	Phenols, Total	0.019	0.014	0.006	NA	NA
	Strontium	0.000	0.000	0.000	NA	NA
	Oil & Grease	2.3	1.7	7.0	0.000	0.000
	Total Suspended Solids	3.5	11.0	66.0	33.0	25.0
	pH, Minimum	6.0	7.7	7.0	NA	NA
	pH, Maximum	10.4	9.2	9.0	NA	7.11

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-45 (Continued)

EFFLUENT FROM SAMPLED PLANTS
mg/l

		PLANT G			PLANT H		
	Temperature (Deg C)	24.0	23.0	24.0	30.0	30.0	30.0
11	1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA
23	Chloroform	NA	NA	NA	NA	NA	NA
44	Methylene chloride	NA	NA	NA	NA	NA	NA
55	Naphthalene	NA	NA	NA	NA	NA	NA
65	Phenol	NA	NA	NA	NA	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA
67	Butyl benzyl phthalate	NA	NA	NA	NA	NA	NA
68	Di-n-butyl phthalate	NA	NA	NA	NA	NA	NA
69	Di-n-octyl phthalate	NA	NA	NA	NA	NA	NA
78	Anthracene	NA	NA	NA	NA	NA	NA
81	Phenanthrene	NA	NA	NA	NA	NA	NA
84	Pyrene	NA	NA	NA	NA	NA	NA
114	Antimony	0.12	0.13	0.17	1.3	1.6	1.7
115	Arsenic	0.000	0.000	0.000	0.000	0.000	0.000
118	Cadmium	0.000	0.000	0.000	0.04	0.000	0.000
119	Chromium, Total	0.000	0.000	0.000	0.000	0.000	0.000
	Chromium, Hexavalent	NA	NA	NA	NA	NA	NA
120	Copper	0.000	0.000	0.05	0.05	0.000	0.000
122	Lead	0.2	0.1	0.3	0.1	0.07	0.19
123	Mercury	NA	NA	NA	NA	NA	NA
124	Nickel	0.000	0.000	0.000	0.000	0.000	0.000
126	Silver	NA	NA	NA	NA	NA	NA
128	Zinc	0.06	0.02	0.06	0.000	0.000	0.000
	Aluminum	0.1	0.1	0.1	0.2	0.000	0.000
	Iron	0.05	0.05	0.1	0.1	0.000	0.000
	Manganese	0.1	0.1	0.1	0.150	0.000	0.000
	Phenols, Total	NA	NA	NA	NA	NA	NA
	Strontium	NA	NA	NA	NA	NA	NA
	Oil & Grease	0.000	0.000	4.2	9.0	0.000	2.0
	Total Suspended Solids	15.0	5.0	9.0	140.0	46.0	25.0
	pH, Minimum	7.5	7.6	8.0	NA	NA	NA
	pH, Maximum	7.6	8.1	8.8	9.0	9.0	9.0

NA - Not Analyzed
* - $\leq$ 0.01

TABLE V-45 (Continued)

EFFLUENT FROM SAMPLED PLANTS
mg/l

		PLANT I	PLANT J
	Temperature (Deg C)	28.0	NA
11	1,1,1-Trichloroethane	NA	NA
23	Chloroform	NA	NA
44	Methylene chloride	NA	NA
55	Naphthalene	NA	NA
65	Phenol	NA	NA
66	Bis(2-ethylhexyl)phthalate	NA	NA
67	Butyl benzyl phthalate	NA	NA
68	Di-n-butyl phthalate	NA	NA
69	Di-n-octyl phthalate	NA	NA
78	Anthracene	NA	NA
81	Phenanthrene	NA	NA
84	Pyrene	NA	NA
114	Antimony	0.007	0.110
115	Arsenic	0.006	0.000
118	Cadmium	0.000	0.000
119	Chromium, Total	0.000	0.000
	Chromium, Hexavalent	NA	NA
120	Copper	0.000	0.000
122	Lead	0.000	0.100
123	Mercury	NA	NA
124	Nickel	0.077	0.000
126	Silver	NA	NA
128	Zinc	1.4	0.080
	Aluminum	0.000	0.200
	Iron	0.29	0.200
	Manganese	0.066	0.000
	Phenols, Total	NA	NA
	Strontium	NA	NA
	Oil & Grease	0.000	NA
	Total Suspended Solids	0.000	NA
	pH, Minimum	NA	NA
	pH, Maximum	7.2	NA

NA - Not Analyzed
* - ≤ 0.01

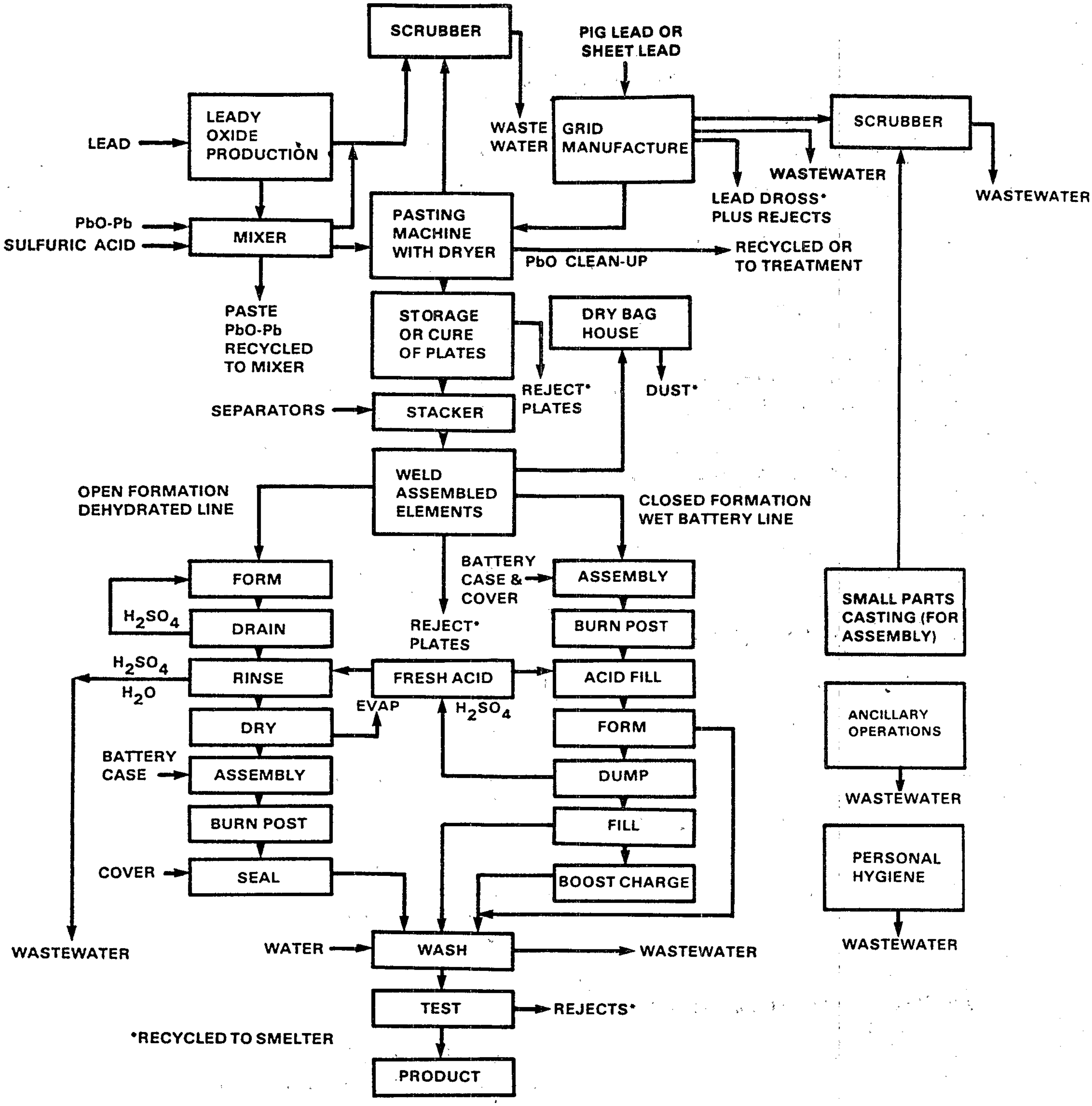


FIGURE V-1
LEAD SUBCATEGORY GENERALIZED MANUFACTURING PROCESS

FIGURE V-2

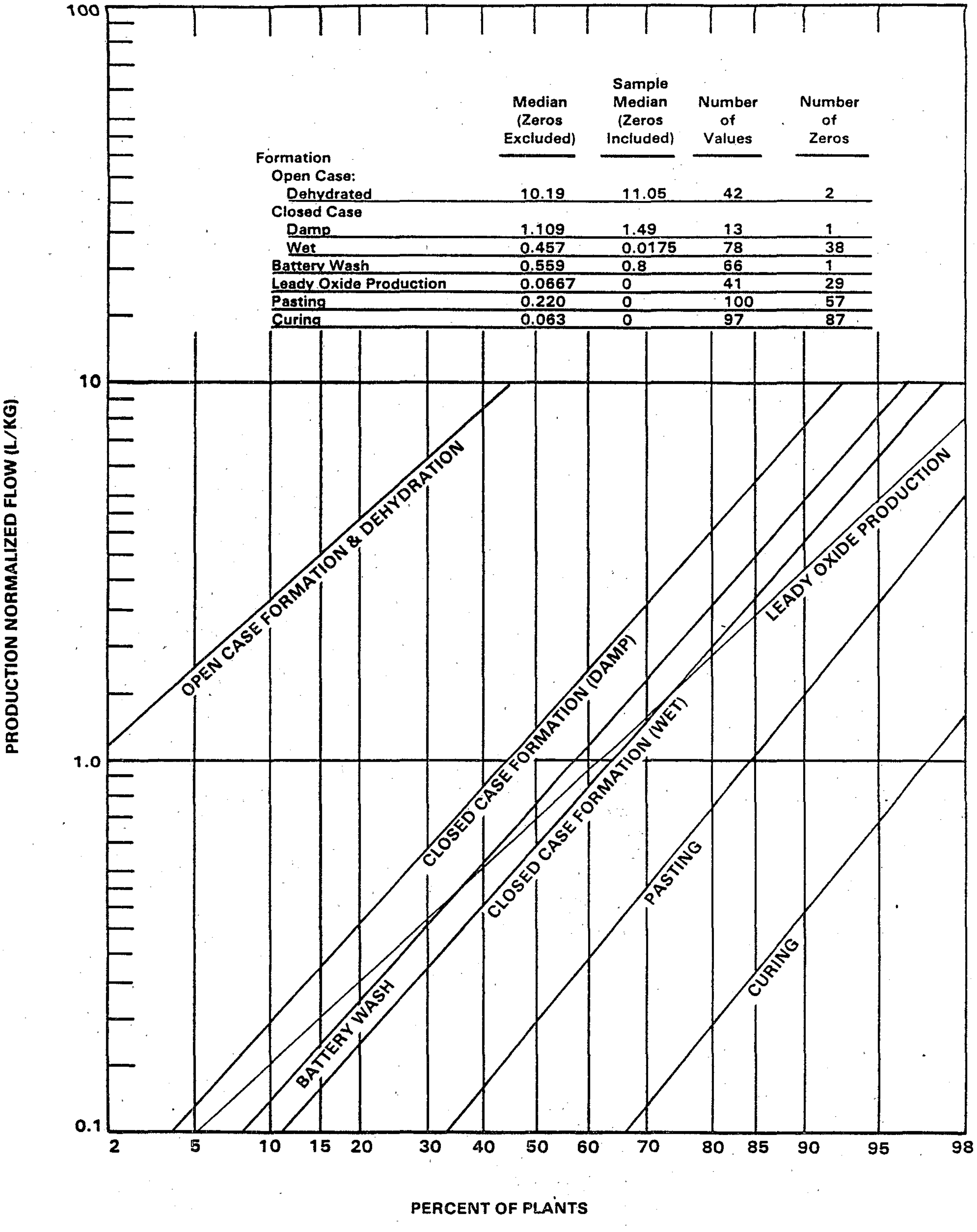
LEAD SUBCATEGORY ANALYSIS

PROCESS ELEMENTS	SPECIFIC WASTEWATER SOURCES
<u>Anodes and Cathodes</u>	
Leady Oxide Production	● Ball Mill Shell Cooling ● Scrubber*
Grid Manufacture	
Grid Casting	● Scrubber*
Mold Release Formulation	● Equipment Wash
Direct Chill Casting	● Contact Cooling
Lead Rolling	● Spent Emulsion Solution
Paste Preparation and Application	● Equipment and Floor Area Cleanup ● Scrubber*
Curing	● Steam Curing ● Humidity Curing
Closed Formation (In Case)	
Single Fill	● Contact Cooling ● Formation Area Washdown ● Scrubber*
Double Fill	● Contact Cooling ● Scrubber* ● Product Rinse ● Formation Area Washdown
Fill and Dump	● Contact Cooling ● Scrubber* ● Product Rinse ● Formation Area Washdown
Open Formation (Out of Case)	
Wet	● Plate Rinse ● Spent Formation Electrolyte ● Formation Area Washdown ● Scrubber*

FIGURE V-2 (Continued)

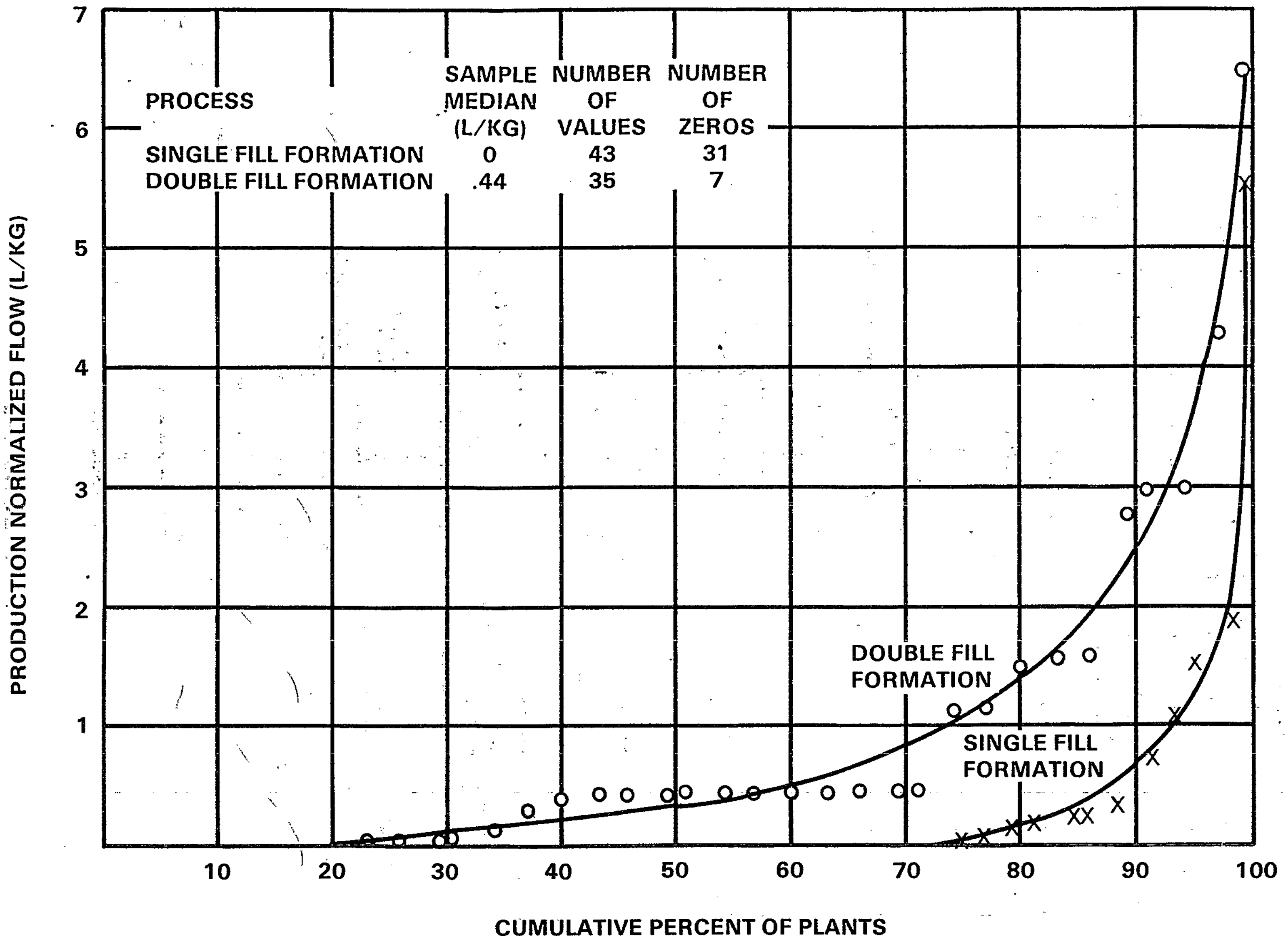
LEAD SUBCATEGORY ANALYSIS

PROCESS ELEMENTS	SPECIFIC WASTEWATER SOURCES
Dehydrated	● Formation Area Washdown ● Plate Rinse ● Vacuum Pump Seals ● Scrubber*
Plate Soak	● Soaking Acid
<u>Ancillary Operations</u>	
Assembly - Small Parts Casting	● Scrubber*
Battery Wash	
With Detergent	● Detergent Battery Wash
Water Only	● Water Only Battery Wash
Floor Wash	● Floor Wash ● Power Floor Scrubbers
Wet Air Pollution Control	● Scrubber Blowdown From *'d Processes
Battery Repair	● Battery Repair Area Wash
Laboratory	● Laboratory Sinks ● Battery Electrolyte ● Laboratory Wash ● Scrubber Blowdown
Truck Wash	● Truck Wash
<u>Personal Hygiene</u>	
Hand Wash	● Hand Wash
Respirator Wash	● Respirator Wash and Rinse
Laundry	● Clothing Wash and Rinse



	Median (Zeros Excluded)	Sample Median (Zeros Included)	Number of Values	Number of Zeros
Formation				
Open Case:				
Dehydrated	10.19	11.05	42	2
Closed Case				
Damp	1.109	1.49	13	1
Wet	0.457	0.0175	78	38
Battery Wash	0.559	0.8	66	1
Leady Oxide Production	0.0667	0	41	29
Pasting	0.220	0	100	57
Curing	0.063	0	97	87

FIGURE V-3
PERCENT PRODUCTION NORMALIZED DISCHARGE FROM LEAD SUBCATEGORY PROCESS OPERATIONS



PROCESS	SAMPLE MEDIAN (L/KG)	NUMBER OF VALUES	NUMBER OF ZEROS
SINGLE FILL FORMATION	0	43	31
DOUBLE FILL FORMATION	.44	35	7

FIGURE V-4
PRODUCTION NORMALIZED DISCHARGE FROM DOUBLE AND SINGLE FILL FORMATION

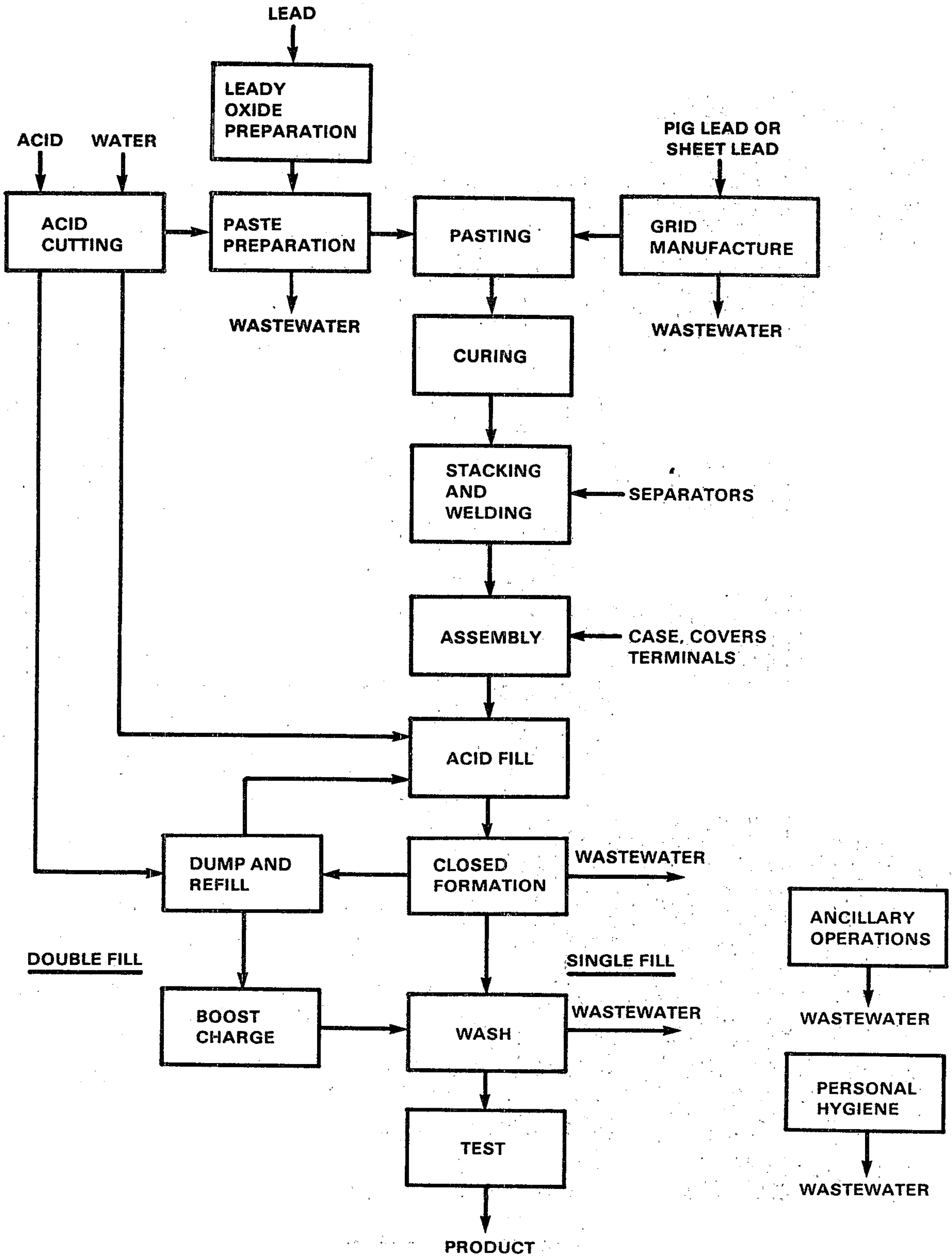


FIGURE V-5
PRODUCTION OF CLOSED FORMATION WET BATTERIES

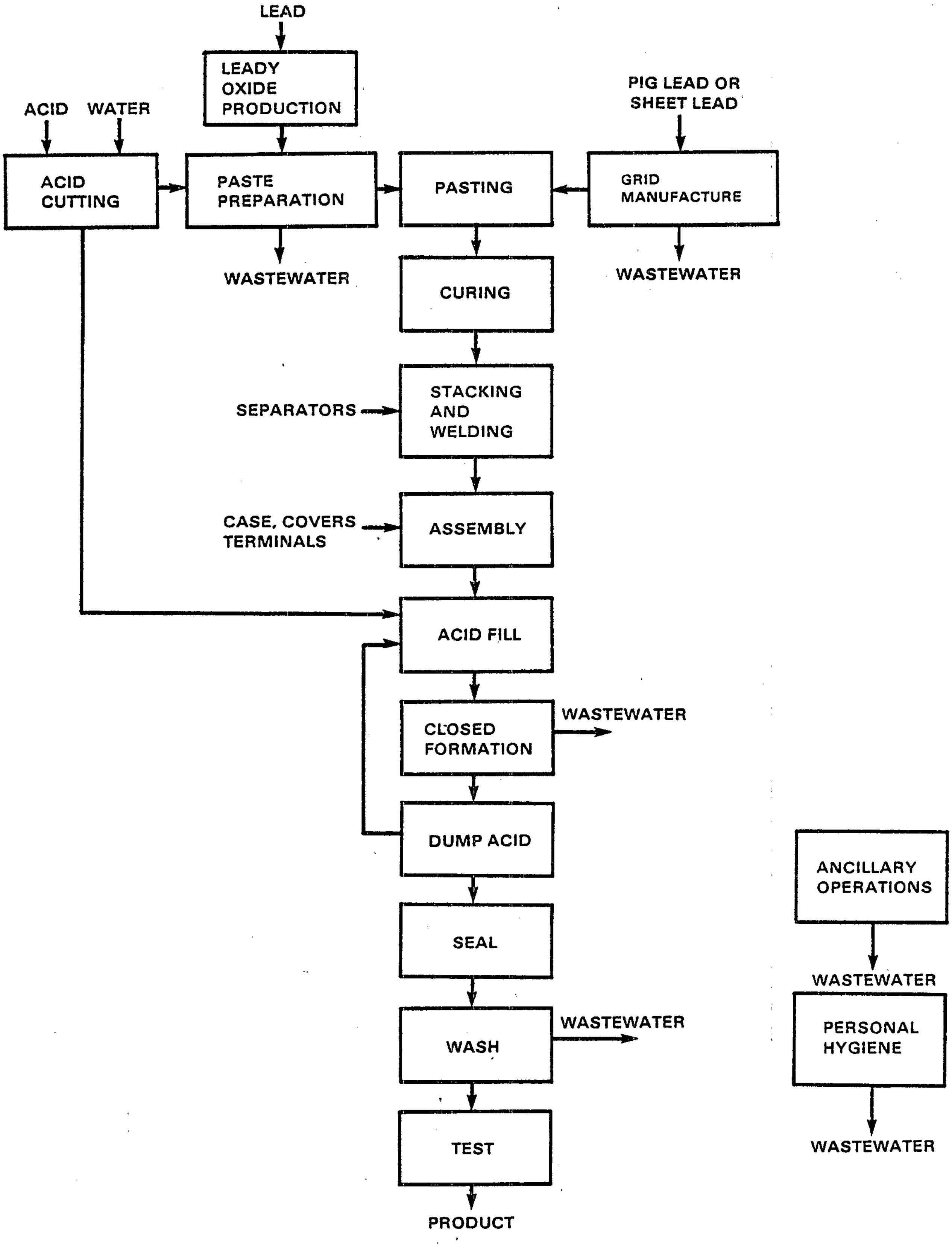


FIGURE V-6
PRODUCTION OF DAMP BATTERIES

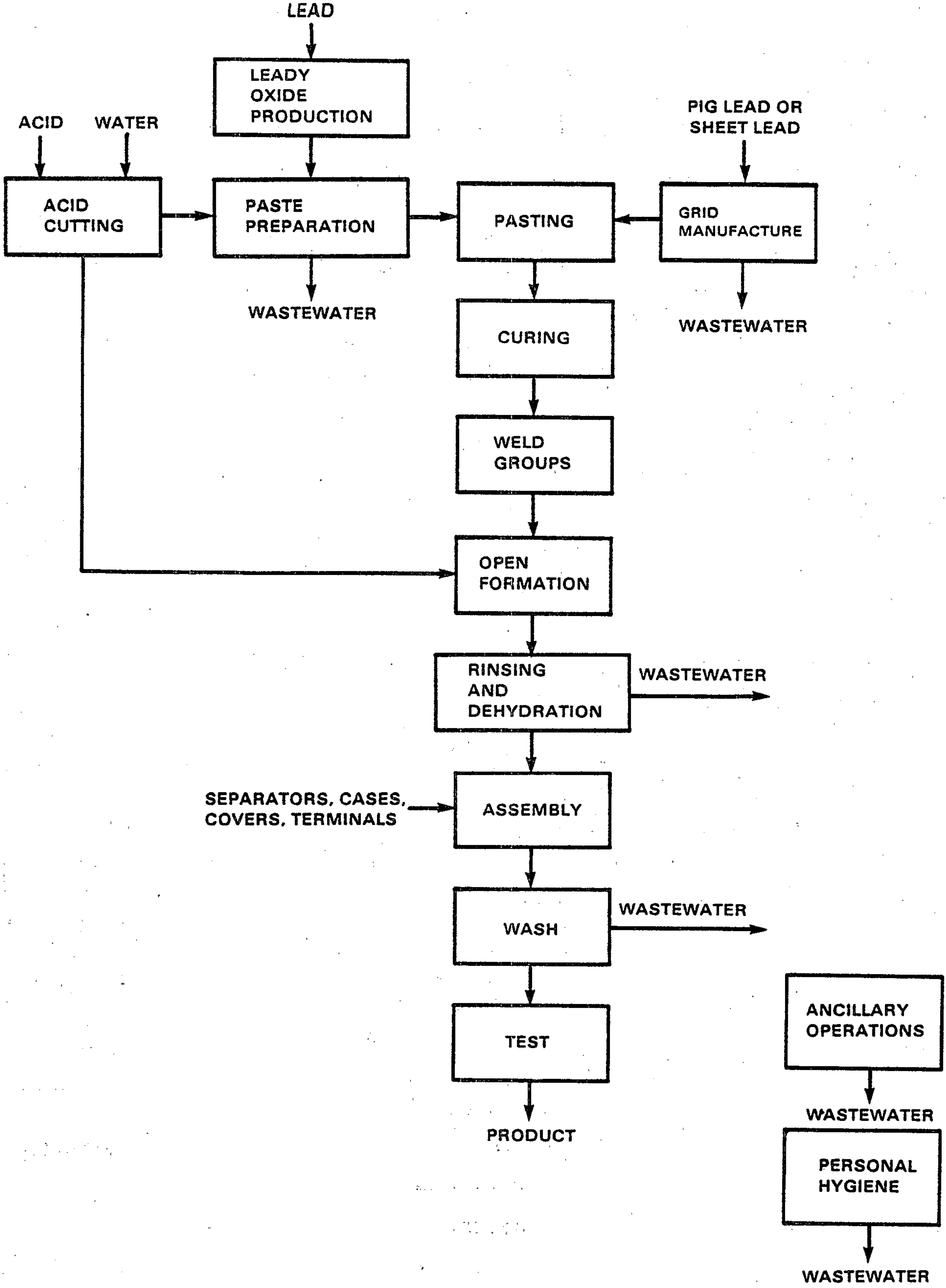


FIGURE V-7
PRODUCTION OF DEHYDRATED BATTERIES

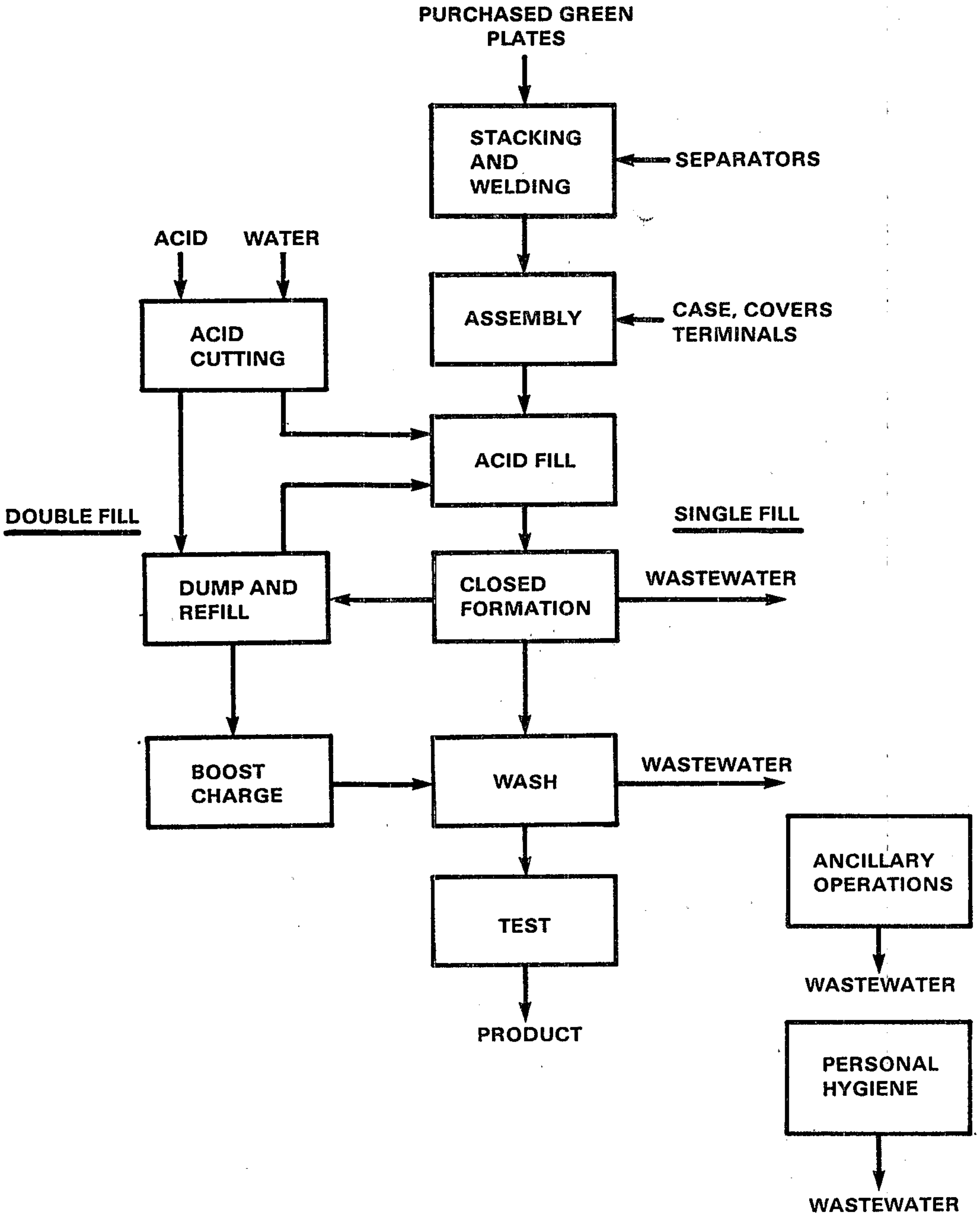


FIGURE V-8
PRODUCTION OF BATTERIES FROM GREEN (UNFORMED) ELECTRODES

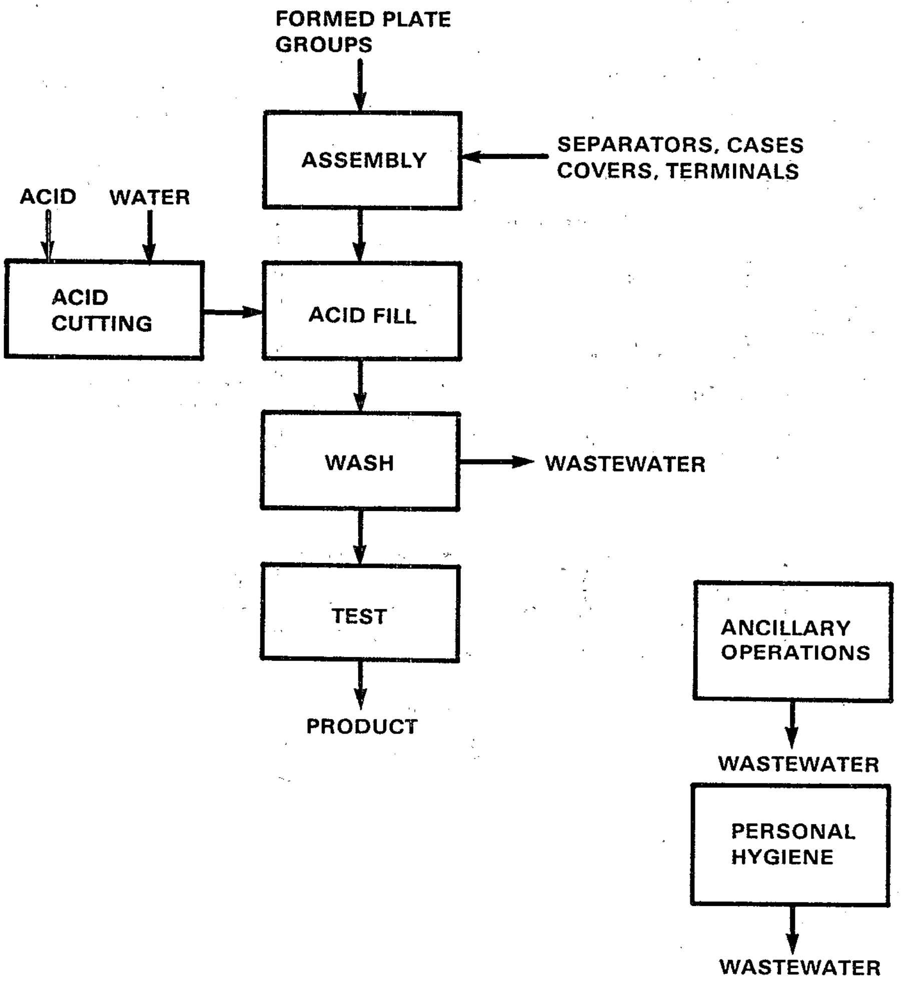


FIGURE V-9
PRODUCTION OF BATTERIES FROM PURCHASED FORMED PLATES

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

The priority, nonconventional, 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 in this section. The selected priority pollutants are presented in numerical order and are followed by nonconventional 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 the lead subcategory. The rationale for that final selection is included.

VERIFICATION PARAMETERS

Pollutant parameters selected for verification sampling and analysis for the lead subcategory are listed in Section V (page 118). 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, the ambient water criterion is 18.4 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.

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 based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-7}, 10^{-6}, and 10^{-5}. The corresponding recommended criteria are 0.000019 mg/l, 0.00019 mg/l, and 0.0019 mg/l.

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.

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 extremely 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 conducting 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 potential concinogenic effects due to exposure to methylene chloride through ingestion of contaminated water and contaiminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6} and 10^{-7}. The corresponding recommended criteria are 0.0019 mg/l, 0.00019 mg/l, and 0.000019 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.

There are insufficient data on which to base any ambient water criterion.

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 0.022 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.

<u>Phenol(65)</u>. 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 3.5 mg/l.

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."

<u>Phthalate Esters (66-71)</u>. 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 terephthalic 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. Available data show that adverse effects on freshwater aquatic life occur at phthalate ester concentrations as low as 0.003 mg/l.

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 it is expected that they will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in POTW. On the same basis it is expected that di-n-octyl phthalate will not be biochemically oxidized to a significant extent by biological treatment in a POTW. An EPA study of seven POTWs revealed that for all but di-n-octyl phthalate, which was not studied, removals ranged from 62 to 87 percent.

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.

Phthalate esters selected for verification analysis in the lead subcategory - are discussed individually below.

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 15 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criteria is determined to be 50 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 discussed in the general discussion of phthalate esters.

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 34 mg/l. If contaminated aquatic organisms are consumed, excluding the consumption of water, the ambient water criterion is 154 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.

Based on these data it is expected that di-n-butyl phthalate will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in POTW.

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.

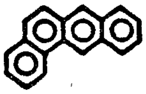
Biological treatment in POTW is expected to lead to little or no removal of di-n-octyl phthalate.

<u>Polynuclear Aromatic Hydrocarbons(72-84)</u>. 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.

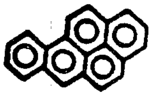
72 Benzo(a)anthrancene (1,2-benzanthracene)

m.p. 162°C



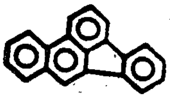
73 Benzo(a)pyrene (3,4-benzopyrene)

m.p. 176°C



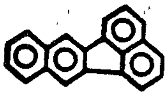
74 3,4-Benzofluoranthene

m.p. 168°C



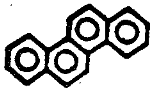
75 Benzo(k)fluoranthene (11,12-benzofluoranthene)

m.p. 217°C



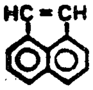
76 Chrysene (1,2-benzphenanthrene)

m.p. 255°C



77 Acenaphthylene
HC=Ch

m.p. 92°C

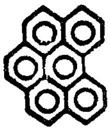


78 Anthracene

m.p. 216°C

79 Benzo(ghi)perylene (1,12-benzoperylene)

m.p. not reported



80 Fluorene (alpha-diphenylenemethane)

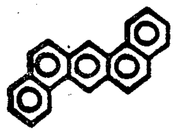
m.p. 116°C

81 Phenanthrene

m.p. 101°C

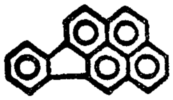
82 Dibenzo(a,h)anthracene (1,2,5,6-dibenzoanthracene)

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 mass spectrometry (GCMS). 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 should be zero based on the non-threshold assumption for these chemicals. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the life time are estimated at 10^{-5}, 10^{-6}, and 10^{-7} with corresponding recommended criteria of 0.000028 mg/l, 0.0000028 mg/l, and 0.00000028 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.

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 nonmetal 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 epidemiology 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 appetite, 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 0.146 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is determined to be 45 mg/l. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited for human health risks.

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 due to exposure to arsenic through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption of this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6} and 10^{-7}. The corresponding recommended criteria are 2.2×10^{-7} mg/l, 2.2×10^{-6} mg/l, and 2.2×10^{-5} mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water concentration should be less than 1.75×10^{-4} mg/l to keep the increased lifetime cancer risk below 10^{-5}. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited for human health risks.

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. Two Federal agancies have already recognized the potential adverse human health effects posed by the use of sludge on cropland. The FDA recommends that sludge containing over 30 mg/kg of cadmium should not be used on agricultured land. Sewage sludge contains 3 to 300 mg/kg (dry basis) of cadmium (mean = 10 mg/kg). The USDA also recommends placing limits on the total cadmium from sludge that may be applied to land.

Chromium(119). Chromium is an elemental metal usually found as a chromite ($FeO \bullet Cr_2O_3$). 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 (trivalent) ingested through water and contaminated aquatic organisms, the recommended water qualtiy criterion is 170 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water criterion for trivalent chromium is 3,443 mg/l. The ambient water quality criterion for hexavalent chromium is recommended to be identical to the existing drinking water standard for total chromium which is 0.050 mg/l.

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 5.6 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 [$CuCO_3 \bullet Cu(OH)_2$], azurite [$2CuCO_3 \bullet Cu(OH)_2$], 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 freshwater aquatic life is 0.0056 mg/l as a 24-hour average, and 0.012 mg/l maximum concentration at a hardness of 50 mg/l $CaCO_3$. For total recoverable copper the criterion to protect freshwater aquatic life is 5.6 x 10^{-3} mg/l as a 24-hour average.

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.

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 co-carcinogen in some species of experimental animals. Lead is teratogenic in experimental animals. Mutagenicity 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. Available data show that adverse effects on aquatic life occur at concentrations as low as 7.5×10^{-4} mg/l of total recoverable lead as a 24-hour average with a water hardness of 50 mg/l as $CaCO_3$.

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.

<u>Mercury</u>. 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 insoluble 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 0.000144 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 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 0.0134 mg/l. If contaminated aquatic organisms are consumed, excluding consumption of water, the ambient water criterion is determined to be 0.100 mg/l. Available data show that adverse effects on aquatic life occur for total recoverable nickel concentrations as low as 0.0071 mg/l as a 24-hour average.

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.

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 0.050 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, concentrations in ambient water should not exceed 5 mg/l. Available data show that adverse effects on aquatic life occur at concentrations as low as 0.047 mg/l as a 24-hour average.

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 usefuleness of municipal sludge.

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 nonconventional 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.

There is increasing evidence that dissolved aluminum has substantial adverse effects on human health. Aluminum has been implicated by several studies in the development of Alzheimer's disease (progressive senile dementia). This disease is associated with the formation of tangled bunches of nerve fibers or "neurofibrillary tangles" (NFT). Autopsy studies have shown that aluminum is present in 90 percent of the nuclei of NFT neurons. It is present in less than 6 percent of the nuclei of normal neurons. This trend is also apparent in the cytoplasm of NFT neurons, although less prominent than in the nuclei: aluminum was found in 29.4 percent of the cytoplasms of NFT neurons and 11.1 percent of the cytoplasms of normal neurons.

Brains of individuals suffering from several other neurological diseases have also displayed elevated concentrations of aluminum. These diseases include Huntington's disease, Parkinsons' disease, progressive supranuclear palsy, acoustic neuroma, and Guamanian amyotrophic lateral sclerosis (ALS).

These increased concentrations of aluminum may be a result of the development of the disease, rather than a contributing cause; however, this possibility seems less likely in light of several recent studies correlating high concentrations of aluminum in the environment to a high incidence of several of these neurological disorders. These and other studies are discussed in greater detail in the report "Aluminum: An Environmental and Health Effects Assessment," cited as a reference in this document. Although much work remains to be done on this subject, the Agency believes that the evidence points to a much broader neurotoxic role for aluminum than had previously been assumed.

In addition, mildly alkaline conditions can cause precipitation of aluminum as the hydroxide. When aluminum hydroxide precipitates in waterways or bodies of water, it can blanket the bottom, having an adverse effect on the benthos and on aquatic plant life rooted on the bottom. Aluminum hydroxide, like many precipitates, can also impair the gill action of fish when present in large amounts.

Alum, an aluminum salt with the chemical formula $Al_2(SO_4)_3 \bullet 14\ H_2O$ is used as a coagulant in municipal and industrial wastewater treatment. This form is different from dissolved aluminum and aluminum hydroxide, which are both harmful pollutants. The amount of dissolved aluminum in finished water does not generally depend upon the amount of alum used as a coagulant, unless a large excess is used. The alum is contained in the treatment sludge; very little passes through into the effluent.

Similarly, the amount of aluminum hydroxide in finished water does not depend on the amount of alum used in coagulation, but rather on the pH and the concentration of dissolved aluminum. Therefore, the use of alum as a coagulant does not result in large amounts of either aluminum or aluminum hydroxide in finished water. There are no data available on the POTW removal efficiency for the pollutant aluminum.

Iron. Iron is a nonconventional 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.

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 nonconventional 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 nonconventional 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 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 from 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 nonconventional 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 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 chemicals 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 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."

SPECIFIC POLLUTANTS CONSIDERED FOR REGULATION

For the lead subcategory, discussion of individual pollutant parameters selected for consideration for specific regulation are based on an evaluation of pollutant concentrations in total raw wastewater streams from eight plants (Table V-34, page 220), an evaluation of pollutant concentrations in process elements streams (Tables V-5 to V-31, pages 178 to 210), and an evaluation of the raw materials and the manufacturing processes employed.

Parameters Selected for Consideration for Specific Regulation. Based on the subcategory pollutant selection analysis, 15 pollutant parameters are considered for specific regulation. The parameters selected are: antimony, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, aluminum, iron, manganese, oil and grease, total suspended solids and pH. These pollutants were observed at significant levels in raw wastewater produced in the subcategory and are amenable to control by identified wastewater treatment and control practices.

Antimony concentrations appeared in 11 of 20 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 0.536 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, and since antimony is used as a raw material, it is considered for specific regulation in this subcategory.

Cadmium concentration appeared in 17 of 20 total raw wastewater 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 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 19 of 19 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 (detergent) raw wastewater samples. Specific treatment methods can reduce chromium below this level. Therefore, chromium is considered for specific regulation.

Copper concentrations appeared in 19 of 19 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 9.83 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. Some of the measured 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 eight plants in the lead subcategory. The maximum concentration was 135.4 mg/l in the total raw wastewater streams and as high as 6000 mg/l in the pasting raw wastewater samples. All total raw wastewater streams and most individual process wastewater samples contained concentrations which 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 analyzed for this priority pollutant. Streams from two plants contained this pollutant. The maximum concentration was 0.065 mg/l which was from a battery wash (water only) 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 added in the manufacturing process, specific regulation of mercury is considered in this subcategory.

Nickel concentrations appeared in 17 of 19 total raw wastewater streams in the lead subcategory. The maximum concentration was 2.8 mg/l which appeared in the battery wash (detergent) 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.

Silver concentrations appeared in 8 of 13 total raw wastewater streams analyzed for this priority pollutant 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 grids in this subcategory. Therefore, silver is considered for specific regulation.

Zinc concentrations appeared in all total raw wastewater streams from the eight plants in the lead subcategory. The maximum concentration was 6.8 mg/l in the total raw wastewater streams and as high as 15.2 mg/l in the floor wash 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.

Aluminum concentrations appeared in all total raw wastewater streams that were analyzed for aluminum. The maximum aluminum concentration was 2.8 mg/l in the total raw wastewater streams, and concentrations were as high as 160 mg/l in a truck wash raw wastewater sample. These concentrations are greater than those which can be achieved by specific treatment methods. Therefore, aluminum is considered for specific regulation.

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 1050 mg/l in the truck wash 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. All total raw wastewater samples contained concentrations which were greater than those which can be achieved by specific treatment methods. Therefore, iron is considered for specific regulation.

Manganese concentrations appeared in all total raw wastewater streams that were analyzed for manganese. The maximum manganese concentration was 0.42 mg/l in the total raw wastewater streams, and concentrations were as high as 7.2 mg/l in a truck wash raw wastewater sample. These concentrations are above those which can be achieved by specific treatment methods. Therefore, manganese is considered for specific regulation.

Oil and grease concentrations appeared in all total raw wastewater streams in 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 total raw wastewater streams at concentrations as high as 1300 mg/l. 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. Regulation of pH is considered in this subcategory to maintain the pH within the 7.5 to 10.0 range.

<u>Parameters Not Selected for Specific Regulation</u>. 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 13 total raw wastewater streams analyzed for this priority pollutant. 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 the 13 total raw wastewater streams analyzed for this pollutant. All concentrations were below the quantification level for toxic organic pollutants. 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 in 8 of the 13 total raw wastewater streams which were subjected to analysis for this priority pollutant. 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 the 13 total raw wastewater streams analyzed for this pollutant. 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 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 concentrations appeared in total raw wastewater streams from the lead subcategory. Bis (2-ethylhexyl) phthalate concentrations appeared in all total raw wastewater streams which were analyzed for this priority pollutant at concentrations up to 0.135 mg/l. The other three 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. Specific regulation of these four phthalate esters in the lead subcategory is not considered because these unique detections are not attributable to battery manufacturing waters.

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 (for anthracene and phenathoene) 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 10 of the 19 total raw wastewater streams analyzed for this priority pollutant. In the total raw wastewater streams the maximum concentration was 0.12 mg/l and as high as 0.19 mg/l in a floor wash raw wastewater sample. Arsenic is an additive of lead used in some battery plate grids. However, concentration levels attainable by specific treatment methods are 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. The maximum concentration of 0.039 mg/l which appeared in the battery wash (water only) 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.

Summary

Table VI-1, (page 296) presents the selection of priority pollutant parameters considered for regulation for the lead subcategory. The selection is based on all sampling results. The "Not Detected" notation 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 lead subcategory. "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 the subcategory. "Small Unique Sources" for both screening and verification includes those pollutants which were present only in small amounts and includes those samples which were detected at higher concentrations in the influent or effluent than in the raw process wastewater, were detected at only one plant, or were detected and could not be attributed to this point source category. "Not Treatable" means that concentrations were lower than the level achievable with the specific treatment methods considered in Section VII. The "Regulation" notation includes those pollutants which are considered for regulation. Table VI-2 (page 301) summarizes the selection of nonconventional and conventional pollutant parameters for consideration for specific regulation in the lead subcategory.

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION FOR THE LEAD SUBCATEGORY

Pollutant		
001	Acenaphthene	NQ
002	Acrolein	ND
003	Acrylonitrile	ND
004	Benzene	NQ
005	Benzidine	ND
006	Carbon tetrachloride (tetrachloromethane)	ND
007	Chlorobenzene	ND
008	1,2,4-trichlorobenzene	ND
009	Hexachlorobenzene	ND
010	1,2-dichloroethane	ND
011	1,1,1-trichloroethane	NT
012	Hexachloroethane	ND
013	1,1-dichloroethane	ND
014	1,1,2-trichloroethane	ND
015	1,1,2,2-tetrachloroethane	ND
016	Chloroethane	ND
017	Bis (chloromethyl) ether	ND
018	Bis (2-chloroethyl ether	ND
019	2-chloroethyl vinyl ether (mixed)	ND
020	2-chloronaphthalene	ND
021	2,4,6-trichlorophenol	NQ
022	Parachlorometa cresol	ND
023	Chloroform (trichloromethane)	NT
024	2-chlorophenol	NQ
025	1,2-dichlorobenzene	ND
026	1,3-dichlorobenzene	NQ

LEGEND:

ND = NOT DETECTED
NQ = NOT QUANTIFIABLE
SU = SMALL, UNIQUE SOURCES
NT = NOT TREATABLE
REG = REGULATION CONSIDERED

TABLE VI-1 (Continued)

PRIORITY POLLUTANT DISPOSITION FOR THE LEAD SUBCATEGORY

Pollutant		
027	1,4-dichlorobenzene	ND
028	3,3-dichlorobenzidine	ND
029	1,1-dichloroethylene	ND
030	1,2-trans-dichloroethylene	ND
031	2,4-dichlorophenol	NQ
032	1,2-dichloropropane	ND
033	1,2-dichloropropylene (1,2-dichloropropene)	ND
034	2,4-dimethylphenol	ND
035	2,4-dinitrotoluene	ND
036	2,6-dinitrotoluene	ND
037	1,2-diphenylhydrazine	ND
038	Ethylbenzene	NQ
039	Fluoranthene	NQ
040	4-chlorophenyl phenyl ether	ND
041	4-bromophenyl phenyl ether	ND
042	Bis(2-chloroisopropyl) ether	ND
043	Bis (2-chloroethoxyl) methane	ND
044	Methylene chloride (dichloromethane)	NQ
045	Methyl chloride (chloromethane)	ND
046	Methyl bromide (bromomethane)	ND
047	Bromoform (tribromomethane)	ND
048	Dichlorobromomethane	NQ
049	Trichlorofluoromethane	ND
050	Dichlorodifluoromethane	ND
051	Chlorodibromomethane	NQ
052	Hexachlorobutadiene	ND
053	Hexachlorocyclopentadiene	ND
054	Isophorone	ND
055	Naphthalene	NT
056	Nitrobenzene	ND

TABLE VI-1 (Continued)

PRIORITY POLLUTANT DISPOSITION FOR THE LEAD SUBCATEGORY

Pollutant		
057	2-nitrophenol	ND
058	4-nitrophenol	ND
059	2,4-dinitrophenol	ND
060	4,6-dinitro-o-cresol	ND
061	N-nitrosodimethylamine	ND
062	N-nitrosodiphenylamine	ND
063	N-nitrosodi-n-propylamine	ND
064	Pentachlorophenol	ND
065	Phenol	NQ
066	Bis(2-ethylhexyl) phthalate	SU
067	Butyl benzylphthalate	SU
068	Di-n-butyl phthalate	SU
069	Di-n-octyl phthalate	SU
070	Diethyl phthalate	ND
071	Dimethyl phthalate	ND
072	1,2-benzanthracene (benzo(a)anthracene)	NQ
073	Benzo(a)pyrene (3,4-benzopyrene)	NQ
074	3,4-Benzofluoranthene (benzo(b)fluoranthene)	NQ
075	11,12-benzofluoranthene (benzo(b)fluoranthene)	NQ
076	Chrysene	NQ
077	Acenaphthylene	ND
078	Anthracene	SU
079	1,12-benzoperylene (benzo(ghi)perylene)	ND
080	Fluorene	NQ
081	Phenanthrene	SU
082	1,2,5,6-dibenzanthracene dibenzo(h)anthracene	ND
083	Indeno(1,2,3-cd) pyrene (2,3-o-phenylene pyrene)	ND
084	Pyrene	NQ
085	Tetrachloroethylene	ND

TABLE VI-1 (Continued)

PRIORITY POLLUTANT DISPOSITION FOR THE LEAD SUBCATEGORY

Pollutant		
086	Toluene	SU
087	Trichloroethylene	NQ
088	Vinyl chloride (chloroethylene)	ND
089	Aldrin	ND
090	Dieldrin	ND
091	Chlorodane (technical mixture and metabolites)	ND
092	4,4-DDT	ND
093	4,4-DDE (p,p-DDX)	ND
094	4,4-DDD (p,p-TDE)	ND
095	Alpha-endosulfan	ND
096	Beta-endosulfan	ND
097	Endosulfan sulfate	ND
098	Endrin	ND
099	Endrin aldehyde	ND
100	Heptachlor	ND
101	Heptachlor epoxide (BHC hexachlorohexane)	NQ
102	Alpha-BHC	NQ
103	Beta-BHC	ND
104	Gamma-BHC (lindane)	ND
105	Delta-BHC (PCB-polychlorinated biphenyls)	ND
106	PCB-1232 (Arochlor 1242)	ND
107	PCB-1254 (Arochlor 1254)	ND
108	PCB-1221 (Arochlor 1221)	ND
109	PCB-1232 (Arochlor 1232)	ND
110	PCB-1248 (Arochlor 1248)	ND
111	PCB-1260 (Arochlor 1260)	ND
112	PCB-1016 (Arochlor 1016)	ND
113	Toxaphene	ND
114	Antimony	REG
115	Arsenic	NT
116	Asbestos	ND
117	Beryllium	NQ
118	Cadmium	REG
119	Chromium	REG
120	Copper	REG
121	Cyanide	NQ
122	Lead	REG

TABLE VI-1 (Continued)

PRIORITY POLLUTANT DISPOSITION FOR THE LEAD SUBCATEGORY

Pollutant		
123	Mercury	REG
124	Nickel	REG
125	Selenium	ND
126	Silver	REG
127	Thallium	ND
128	Zinc	REG
129	2,3,7,8-tetrachlorodibenzo-p-dioxin	ND

TABLE VI-2

OTHER POLLUTANTS CONSIDERED FOR REGULATION IN THE LEAD SUBCATEGORY

Aluminum

Iron

Manganese

TSS

Oil and Grease

pH

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 lead subcategory of the battery manufacturing industrial point source category. Included are discussions of individual end-of-pipe treatment technologies and in-plant technologies. These treatment technologies are widely used in many industrial categories, and data and information to support their effectiveness has been drawn from a similarly wide range of sources and data bases.

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 lead subcategory plants. Each description includes a functional description and discussion 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 wastewaters characteristically may be acid or alkaline; may contain substantial levels of dissolved or particulate metals including cadmium, chromium, lead, mercury, nickel, silver, zinc and manganese; contain only small or trace amounts of toxic organics; and are generally free from strong chelating agents. The 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 technologies.

MAJOR TECHNOLOGIES

In Sections IX, X, XI, and XII the rationale for selecting treatment systems is discussed. The individual technologies used in the system are described here. The major end-of-pipe technologies for treating lead subcategory wastewaters are: (1) chemical reduction of chromium, (2) chemical precipitation, (3) cyanide precipitation, (4) granular bed filtration, (5) pressure filtration, (6) settling, and (7) skimming. 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.

1. 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:

$$3\ SO_2 + 3\ H_2O \ \text{---->}\ 3\ H_2SO_3$$

$$3\ H_2SO_3 + 2H_2CrO_4 \ \text{---->}\ Cr_2(SO_4)_3 + 5\ H_2O$$

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-13 (Page 439) 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 most usually required to treat electroplating and metal surfacing rinse waters, but may also be required 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/l are readily attained, and concentrations of 0.01 mg/l are considered to be attainable by properly maintained and operated equipment.

Advantages and Limitations. The major advantage of chemical reduction to reduce 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 removal depends on 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. However, small amounts of sludge may be collected as the result of 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 conversion coating and noncontact cooling.

2. 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, fluorides as calcium fluoride and arsenic as calcium arsinate.

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 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 very small amount of metal will remain dissolved in the wastewater after precipitation is complete. 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. In specific instances, a sacrifical ion such as iron or aluminum may be added to aid in the removal of toxic metals by co-precipitation process and reduce the fraction of a specific metal in the precipitate.

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 antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, zinc, aluminum, cobalt, iron, manganese, molybdenum and tin. 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 more important factors affecting precipitation effectiveness are:

1. Maintenance of an appropriate (usually 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 (see appropriate solids removal technologies).

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 427), and by plotting effluent zinc concentrations against pH as shown in Figure VII-3 (page 429). Figure VII-3 was obtained from Development Document for the Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Zinc Segment of Nonferrous Metals Manufacturing Point Source Category, U.S. E.P.A., EPA 440/1-74/033, November, 1974. Figure VII-3 was plotted from the sampling data from several facilities with metal finishing operations. It is partially illustrated by data obtained from 3 consecutive days of sampling at one metal processing plant (47432) as displayed in Table VII-1 (page 404). Flow through this system is approximately 49,263 l/hr (13,000 gal/hr).

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; intermediate values were achieved on the third day, when pH values were less than desirable but in between those for the first and second days.

Sodium hydroxide is used by one facility (plant 439) 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 22,700 l/hr (6,000 gal/hr). These data displayed in Table VII-2 (page 404) indicate that the system was operated efficiently. Effluent pH was controlled within the range of 8.6 to 9.3, and, while raw waste loadings were not unusually high, most toxic metals were removed to very low concentrations.

Lime and sodium hydroxide (combined) 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 (page 405) shows sampling data from this system, which uses lime and sodium hydroxide for pH adjustment and 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 19,000 l/hr (5,000 gal/hr).

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.

<u>Sulfide precipitation</u> 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, (page 405). (Source: Lange's Handbook of

Chemistry). 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 (page 406). 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 for the metal hydroxides. 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 trivalent 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:

$$CrO_3 + FeS + 3H_2O \longrightarrow Fe(OH)_3 + Cr(OH)_3 + S$$

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 (page 407) 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.

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-2 (page 428) (Source: "Heavy Metals Removal," by Kenneth Lanovette, Chemical Engineering/Deskbook Issue, October 17, 1977) explain this phenomenon.

Co-precipitation With Iron. The presence of substantial quantites of iron in metal bearing wastewaters before treatment has been shown to improve the removal of toxic metals. In some cases this iron is an integral part of the industrial wastewater; in other cases iron is deliberately added as a pre or first step of treatment. The iron functions to improve toxic metal removal by three mechanisms: the iron co-precipitates with toxic metals forming a stable precipitate which desolubilizes the toxic metal; the iron improves the settleability of the precipitate; and the large amount of iron reduces the fraction of toxic metal in the precipitate. Co-precipitation with iron has been practiced for many years incidentally when iron was a substantial consitutent of raw wastewater and intentionally when iron salts were added as a coagulant aid. Aluminum or mixed iron-aluminum salt also have been used. The addition of iron for co-precipitation to aid in toxic metals removal is considered a routine part of state-of-the-art lime and settle technology which should be implemented as required to achieve optimal removal of toxic metals.

Co-precipitation using large amounts of ferrous iron salts is known as ferrite co-precipitation because magnetic iron oxide or ferrite is formed. The addition of ferrous salts (sulfate) is followed by alkali precipitation and air oxidation. The resultant precipitate is easily removed by filtration and may be removed magnetically. Data illustrating the performance of ferrite co-precipitation is shown in Table VII-7, (page 408).

Advantages and Limitations. Chemical precipitation has proved 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 with mixed wastewaters and treatment chemicals, or because of the potentially hazardous situation involved with the storage and handling of those chemicals. Battery manufacturing wastewaters do not normally contain chelating agents or complex pollutant matrix formations which would interfere with or limit the use of chemical precipitation. 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, lime precipitation usually makes recovery of the precipitated metals difficult, because of the heterogeneous nature of most lime 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 restrict 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 insoluble sulfides reduces 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 additional wastewater 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 to 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 battery manufacturing category. As noted earlier, sedimentation to remove precipitates is discussed separately.

Use in Battery Manufacturing Plants. Chemical precipitation is used at 81 battery manufacturing plants. 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.

3. 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 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 a pH of either 8 or 10, the residual cyanide concentration measured is twice that 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 percent 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-8 (page 408) presents cyanide precipitation data from three coil coating plants. A fourth plant was visited for the purpose of observing plant testing of the cyanide precipitation system. Specific data from this facility are not included because: (1) the pH was usually well below the optimum level of 9.0; (2) the historical treatment data were not obtained using the standard cyanide analysis procedure; and (3) matched input-output data were not made available by the plant. Scanning the available data indicates that the raw waste CN level was in the range of 25.0; the pH 7.5; and treated CN level was from 0.1 to 0.2.

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.

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.

4. 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 multi-media filters may be arranged to maintain relatively distinct layers by virtue of balancing the forces of gravity, flow, and buoyancy 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 (page 439) 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.

Auxilliary 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 carry-over 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:

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-9 (page 409).

Advantages and Limitations. The principal advantages of granular bed filtration are its comparatively (to other filters) 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.

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.

5. 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 441) 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, a filter made of cloth or synthetic fiber is mounted. 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 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.

6. 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 volume tank or lagoon so that gravitational settling can occur. Figure VII-16 (page 442) 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 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.

Settling is based on the ability of gravity (Newton's Law) to cause small particles to fall or settle (Stokes' Law) through the fluid they are suspended in. Presuming that the factors affecting chemical precipitation are controlled to achieve a readily settleable precipitate, the principal factors controlling settling are the particle characteristics and the upflow rate of the suspending fluid. When the effective settling area is great enough to allow settling, any increase in the effective settling area will produce no increase in solids removal.

Therefore, if a plant has installed equipment that provides the appropriate overflow rate, the precipitated metals, including lead, in the effluent can be effectively removed. The number of settling devices operated in series or in parallel by a facility is not important with regard to suspended solids removal, but rather that the settling devices provide sufficient effective settling area.

Another important facet of sedimentation theory is that diminishing removal of suspended solids is achieved for a unit increase in the effective settling area. Generally, it has been found that suspended solids removal performance varies with the effective up-flow rate. Qualitatively the performance increases asymptotically to a maximum level beyond which a decrease in up-flow rate provides incrementally insignificant increases in removal. This maximum level is dictated by particle size distribution, density characteristic of the particles and the water matrix, chemicals used for precipitation and pH at which precipitation occurs.

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 movement rate particle size and density, and the surface area of the basin.

The data displayed in Table VII-10 (page 409) indicate suspended solids removal efficiencies in settling systems. The mean effluent TSS concentration obtained by the plants shown in Table VII-10 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.

<u>Advantages and Limitations</u>. 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.

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 from 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.

7. 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 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 in increasing oil removal efficiency.

<u>Application and Performance</u>. 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 nonemulsified oily waste streams. Sampling data shown in Table VII-11 (page 410) illustrate the capabilities of the technology with both extremely high and moderate oil influent levels.

These data are intended to be illustrative of the very high level of oil and grease removals attainable in a simple two-step oil removal system. Based on the performance of installations in a variety of manufacturing plants and permit requirements that are consistently achieved, 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 metal forming operations 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 as the result of leaching from plastic lines and other materials.

High molecular weight organics in particular are much more soluble in organic solvents than in water. Thus they are much more concentrated in the oil phase that is skimmed than in the wastewater. The ratio of solubilities of a compound in oil and water phases is called the partition coefficient. The logarithm of the partition coefficients for selected polynuclear aromatic hydrocarbon (PAH) and other toxic organic compounds in octanol and water are shown in Table VII-12 (page 411).

A review of priority organic compounds commonly found in metal forming operation 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 toxic organic compounds present in the raw waste. The API oil-water separation system performed notably in this regard, as shown in Table VII-13 (page 412).

Data from five plant days demonstrate removal of organics by the combined oil skimming and settling operations performed on coil coating wastewaters. Days were chosen where treatment system influent and effluent analyses provided paired data points for oil and grease and the organics present. All organics found at quantifiable levels on those days were included. Further, only those days were chosen where oil and grease raw wastewater concentrations exceeded 10 mg/l and where there was reduction in oil and grease going through the treatment system. All plant sampling days which met the above criteria are included below. The conclusion is that when oil and grease are removed, organics also are removed.

	Percent Removal	
Plant-Day	Oil & Grease	Organics
1054-3	95.9	98.2
13029-2	98.3	78.0
13029-3	95.1	77.0
38053-1	96.8	81.3
38053-2	98.5	86.3
Mean	96.9	84.2

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 ten-day 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 removal are installed and operating properly where appropriate.

L&S Performance -- Combined Metals Data Base

A data base known as the "combined metals data base" (CMDB) was used to determine treatment effectiveness of lime and settle treatment for certain pollutants. The CMDB was developed over several years and has been used in a number of regulations. During the development of coil coating and other categorical effluent limitations and standards, chemical analysis data were collected of raw wastewater (treatment influent) and treated wastewater (treatment effluent) from 55 plants (126 data days) sampled by EPA (or its contractor) using EPA sampling and chemical analysis protocols. These data are the initial data base for determining the effectiveness of L&S technology in treating nine pollutants. Each of the plants in the initial data base belongs to at least one of the following industry categories: aluminum forming, battery manufacturing, coil coating (including canmaking), copper forming, electroplating and porcelain enameling. All of the plants employ pH adjustment and hydroxide precipitation using lime or caustic, followed by Stokes' law settling (tank, lagoon or clarifier) for solids removal. An analysis of this data was presented in the development documents for the proposed regulations for coil coating and porcelain enameling (January 1981). Prior to analyzing the data, some values were deleted from the data base. These deletions were made to ensure that the data reflect properly operated treatment systems. The following criteria were used in making these deletions:

- Plants where malfunctioning processes or treatment systems at the time of sampling were identified.
- Data days where pH was less than 7.0 for extended periods of time or TSS was greater than 50 mg/l (these are prima facie indications of poor operation).

In response to the coil coating and porcelain enameling proposals, some commenters claimed that it was inappropriate to use data from some categories for regulation of other categories. In response to these comments, the Agency reanalyzed the data. An analysis of variance was applied to the data for the 126 days of sampling to test the hypothesis of homogeneous plant mean raw and treated effluent levels across categories by pollutant. This analysis is described in the report "A Statistical Analysis of the Combined Metals Industries Effluent Data" which is in the administrative record supporting this rulemaking. Homogeneity is the absence of statistically discernable differences among the categories, while heterogeneity is the opposite, i.e., the presence of statistically discernable differences. The main conclusion drawn from the analysis of variance is that, with the exception of electroplating, the categories included in the data base are generally homogeneous with regard to mean pollutant concentrations in both raw and treated effluent. That is, when data from electroplating facilities are included in the analysis, the hypothesis of homogeneity across categories is rejected. When the electroplating data are removed from the analysis the conclusion changes substantially and the hypothesis of homogeneity across categories is not rejected. On the basis of this analysis, the electroplating data were removed from the data base used to determine limitations for the final coil coating and porcelain enameling regulations and proposed regulations for copper forming, aluminum forming, battery manufacturing, nonferrous metals (Phase I), and canmaking.

The statistical analysis provides support for the technical engineering judgment that electroplating wastewaters are sufficiently different from the wastewaters of other industrial categories in the data base to warrant removal of electroplating data from the data base used to determine treatment effectiveness.

For the purpose of determining treatment effectiveness, additional data were deleted from the data base. These deletions were made, almost exclusively, in cases where effluent data points were associated with low influent values. This was done in two steps. First, effluent values measured on the same day as influent values that were less than or equal to 0.1 mg/l were deleted. Second, the remaining data were screened for cases in which all influent values at a plant were low although slightly above the 0.1 mg/l value. These data were deleted not as individual data points but as plant clusters of data that were consistently low and thus not relevent to assessing treatment. A few data points were also deleted where malfunctions not previously identified were recognized. The data basic to the CMDB are displayed graphically in Figures VII-4 to 12 (Pages 430-438). The ranges of raw waste concentrations for battery manufacturing are also shown in these figures. These levels of metals concentrations in the raw waste are within the range of raw waste concentrations commonly encountered in metals bearing industrial wastewater.

After all deletions, 148 data points from 19 plants remained. These data were used to determine the concentration basis of limitations derived from the CMDB used for the proposed battery manufacturing regulation.

The CMDB was reviewed following its use in a number of proposed regulations (including battery manufacturing). Comments pointed out a few errors in the data, and the Agency's review identified a few transcription errors and some data points that were appropriate for inclusion in the data that had not been used previously because of errors in data record identification numbers. Documents in the record of this rulemaking identify all the changes, the reasons for the changes, and the effect of these changes on the data base. Other comments on the CMDB asserted that the data base was too small and that the statistical methods used were overly complex. Responses to specific comments are provided in a document included in the record of this rulemaking. The Agency believes that the data base is adequate to determine effluent concentrations achievable with lime and settle treatment. The statistical methods employed in the analysis are well known and appropriate statistical references are provided in the documents in the record that describe the analysis.

The revised data base was reexamined for homogeneity. The earlier conclusions were unchanged. The categories show good overall homogeneity with respect to concentrations of the nine pollutants in both raw and treated wastewaters with the exception of electroplating.

The same procedures used in developing proposed limitations from the combined metals data base were then used on the revised data base. That is, certain effluent data associated with low influent values were deleted, and then the remaining data were fit to a lognormal distribution to determine limitations values. The deletion of data was done in two steps. First, effluent values measured on the same day as influent values that were less than or equal to 0.1 mg/l were deleted. Second, the remaining data were screened for cases in which all influent values at a plant were low although slightly above the 0.1 mg/l value. These data were deleted not as individual data points but as plant clusters of data that were consistently low and thus not relevant to assessing treatment.

The revised combined metals data base used for this final regulation consists of 162 data points from 18 plants in the same industrial categories used at proposal. The changes that were made since proposal resulted in slight upward revisions of the concentration bases for the limitations and standards for zinc and nickel. The limitations for iron decrease slightly. The other limitations were unchanged. A comparison of Table VII-21 in the final development document with Table VII-21 in the proposal development document will show the exact magnitude of the changes.

One-day Effluent Values

The same procedures used to determine the concentration basis of the limitations for lime and settle treatment from the CMDB at proposal were used in the revised CMDB for the final limitations. The basic assumption underlying the determination of treatment effectiveness is that the data for a particular pollutant are lognormally distributed by plant. The lognormal has been found to provide a satisfactory fit to plant effluent data in a number of effluent guidelines categories and there was no evidence that the lognormal was not suitable in the case of the CMDB. Thus, we assumed measurements of each pollutant from a particular plant, denoted by X, were assumed followed a lognormal distribution with log mean μ and log variance σ^2. The mean, variance and 99th percentile of X are then:

$$\text{mean of } X = E(X) = \exp(\mu + \sigma^2/2)$$

$$\text{variance of } X = V(X) = \exp(2\mu + \sigma^2)[\exp(\sigma^2) - 1]$$

$$\text{99th percentile} = X_{.99} = \exp(\mu + 2.33\sigma)$$

where exp is e, the base of the natural logarithm. The term lognormal is used because the logarithm of X has a normal distribution with mean μ and variance σ^2. Using the basic assumption of lognormality the actual treatment effectiveness was determined using a lognormal distribution that, in a sense, approximates the distribution of an average of the plants in the data base, i.e., an "average plant" distribution. The notion of an "average plant" distribution is not a strict statistical concept but is used here to determine limits that would represent the performance capability of an average of the plants in the data base.

This "average plant" distribution for a particular pollutant was developed as follows: the log mean was determined by taking the average of all the observations for the pollutant across plants. The log variance was determined by the pooled within plant variance. This is the weighted average of the plant variances. Thus, the log mean represents the average of all the data for the pollutant and the log variance represents the average of the plant log variances or average plant variability for the pollutant.

The one day effluent values were determined as follows:

Let X_{ij} = the jth observation on a particular pollutant at plant i where

$i = 1, \ldots, I$
$j = 1, \ldots, J_i$
I = total number of plants
J_i = number of observations at plant i.

Then $y_{ij} = \ln X_{ij}$

where ln means the natural logarithm.

Then $\bar{y}$ = log mean over all plants

$$= \sum_{i=1}^{I} \sum_{j=1}^{J_i} y_{ij}/n,$$

where n = total number of observations

$$= \sum_{i=1}^{I} J_i$$

and $V(y)$ = pooled log variance

$$= \frac{\sum_{i=1}^{I} (J_i - 1)\, S_i^2}{\sum_{i=1}^{I} (J_i - 1)}$$

where Si^2 = log variance at plant i

$$= \sum_{j=1}^{J_i} (y_{ij} - \bar{y}_i)^2 / (J_i - 1)$$

$\overline{yi}$ = log mean at plant i.

Thus, $\bar{y}$ and $V(y)$ are the log mean and log variance, respectively, of the lognormal distribution used to determine the treatment effectiveness. The estimated mean and 99th percentile of this distribution form the basis for the long term average and daily maximum effluent limitations, respectively. The estimates are

$$\text{mean} = \hat{E}(X) = \exp(\bar{y})\ \Psi n\ (0.5\ V(y))$$

$$\text{99th percentile} = \hat{X}_{.99} = \exp\ [\bar{y} + 2.33\sqrt{V(y)}\ ]$$

where $\Psi(.)$ is a Bessel function and exp is e, the base of the natural logarithms (See Aitchison, J. and J.A.C. Brown, <u>The Lognormal Distribution</u>, Cambridge University Press, 1963). In cases where zeros were present in the data, a generalized form of the lognormal, known as the delta distribution was used (See Aitchison and Brown, op. cit., Chapter 9).

For certain pollutants, this approach was modified slightly to ensure that well operated lime and settle plants in all CMDB categories would achieve the pollutant concentration values calculated from the CMDB. For instance, after excluding the electroplating data and other data that did not reflect pollutant removal or proper treatment, the effluent copper data from the copper forming plants were statistically significantly greater than the copper data from the other plants. This indicated that copper forming plants might have difficulty achieving an effluent concentration value calculated from copper data from all CMDB categories. Thus, copper effluent values shown in Table VII-14 (page 412) are based only on the copper effluent data from the copper forming plants. That is, the log mean for copper is the mean of the logs of all copper values from the copper forming plants only and the log variance is the pooled log variance of the copper forming plant data only. A similar situation occurred in the case of lead. That is, after excluding the electroplating data, the effluent lead data from battery manufacturing were significantly greater than the other categories. This indicated that battery manufacturing plants might have difficulty achieving a lead concentration calculated from all the CMDB categories. The lead values proposed were therefore based on the battery manufacturing lead data only. Comments on the proposed battery manufacturing regulation objected to this procedure and asserted that the lead concentration values were too low. Following proposal, the Agency obtained additional lead effluent data from a battery manufacturing facility with well operated lime and settle treatment. These data were combined with the proposal lead data and analyzed to determine the final treatment effectiveness concentrations. The mean lead concentration is unchanged at 0.12 mg/l but the final one-day maximum and monthly 10-day average maximum increased to 0.42 and 0.20 mg/l, respectively. A complete discussion of the lead data and analysis is contained in a memorandum in the record of this rulemaking.

In the case of cadmium, after excluding the electroplating data and data that did not reflect removal or proper treatment, there were insufficient data to estimate the log variance for cadmium. The variance used to determine the values shown in Table VII-14 for cadmium was estimated by pooling the within plant variances for all the other metals. Thus, the cadmium variability is the average of the plant variability averaged over all the other metals. The log mean for cadmium is the mean of the logs of the cadmium observations only. A complete discussion of the data and calculations for all the metals is contained in the administrative record for this rulemaking.

Average Effluent Values

Average effluent values that form the basis for the monthly limitations were developed in a manner consistent with the method used to develop one-day treatment effectiveness in that the lognormal distribution used for the one-day effluent values was also used as the basis for the average values. That is, we assume a number of consecutive measurements are drawn from the distribution of daily measurements. The average of ten measurements taken during a month was used as the basis for the monthly average limitations. The approach used for the 10 measurements values was employed previously in regulations for other categories and was proposed for the battery manufacturing category. That is, the distribution of the average of 10 samples from a lognormal was approximated by another lognormal distribution. Although the approximation is not precise theoretically, there is empirical evidence based on effluent data from a number of categories that the lognormal is an adequate approximation for the distribution of small samples. In the course of previous work the approximation was verified in a computer simulation study (see "Development Document for Existing Sources Pretreatment Standards for the Electroplating Point Source Category", EPA 440/1-79/003, U.S. Environmental Protection Agency, Washington, D.C., August 1979). We also note that the average values were developed assuming independence of the observations although no particular sampling scheme was assumed.

Ten-Sample Average:

The formulas for the 10-sample limitations were derived on the basis of simple relationships between the mean and variance of the distributions of the daily pollutant measurements and the average of 10 measurements. We assume the daily concentration measurements for a particular pollutant, denoted by X, follow a lognormal distribution with log mean and log variance denoted by μ and σ^2, respectivey. Let $\bar{X}_{10}$ denote the mean of 10 consecutive measurements. The following relationships then hold assuming the daily measurements are independent:

$$\text{mean of } \bar{X}_{10} = E(\bar{X}_{10}) = E(X)$$

$$\text{variance of } \bar{X}_{10} = V(\bar{X}_{10}) = V(X) + 10.$$

Where E(X) and V(X) are the mean and variance of X, respectively, defined above. We then assume that $\bar{X}_{10}$ follows a lognormal distribution with log mean μ_{10} and log standard deviation σ^2. The mean and variance of $\bar{X}_{10}$ are then

$$E(\bar{X}_{10}) = \exp\ (\mu_{10} + 0.5\ \sigma^2_{10})$$
$$V(\bar{X}_{10}) = \exp\ (2\ \mu_{10} + \sigma^2_{10})\ [\exp(\sigma^2_{10})-1]$$

Now, μ_{10} and σ^2_{10} can be derived in terms of μ and σ^2 as

$$\mu_{10} = \mu + \sigma^2/2 - 0.5\ \ln\ [1+(\exp(\sigma^2 - 1)/N]$$
$$\sigma^2_{10} = \ln\ [1+(\exp(\sigma^2) - 1)/N]$$

Therefore, μ_{10} and σ^2_{10} can be estimated using the above relationships and the estimates of μ and σ^2 obtained for the underlying lognormal distribution. The 10 sample limitation value was determined by the estimate of the approximate 99th percentile of the distribution of the 10 sample average given by

$$\widehat{X_{10}}\ (.99) = \exp\ (\hat{\mu}_{10} + 2.33\,\hat{\sigma}_{10}).$$

where $\hat{\mu}_{10}$ and $\hat{\sigma}_{10}$ are the estimates of μ_{10} and σ_{10}, respectively.

Thirty-Sample Average

Monthly average values based on the average of 30 daily measurements were also calculated. These are included because monthly limitations based on 30 samples have been used in the past and for comparison with the 10 sample values. The average values based on 30 measurements are determined on the basis of a statistical result known as the Central Limit Theorem. This Theorem states that, under general and nonrestrictive assumptions, the distribution of a sum of a number of random variables, say n, is approximated by the normal distribution. The approximation improves as the number of variables, n, increases. The Theorem is quite general in that no particular distributional form is assumed for the distribution of the individual variables. In most applications (as in approximating the distribution of 30-day averages) the Theorem is used to approximate the distribution of the average of n observations of a random variable. The result makes it possible to compute approximate probability statements about the average in a wide range of cases. For instance, it is possible to compute a value below which a specified percentage (e.g., 99 percent) of the averages of n observations are likely to fall. Most textbooks state that 25 or 30 observations are sufficient for the approximation to be valid. In applying the Theorem to the distribution of the 30 day average effluent values, we approximate the distribution of the average of 30 observations drawn from the distribution of daily measurements and use the estimated 99th percentile of this distribution.

Thirty-Sample Average Calculation

The formulas for the 30-sample average were based on an application of the Central Limit Theorem. According to the Theorem, the average of 30 observations drawn from the distribution of daily measurements, denoted by $\overline{X}_{30}$, is approximately normally distributed. The mean and variance of $\overline{X}_{30}$ are:

$$\text{mean of } \overline{X}_{30} = E(\overline{X}_{30}) = E(X)$$
$$\text{variance of } \overline{X}_{30} = V(\overline{X}_{30}) = V(X) \div 30.$$

The 30 sample average value was determined by the estimate of the approximate 99th percentile of the distribution of the 30 sample average given by

$$\widehat{X_{30}}(.99) = \widehat{E}(X) + 2.33\sqrt{\widehat{V}(X) \div 30}$$

where
$$\widehat{E}(X) = \exp(\overline{y})\ \psi_n(0.5V(y))$$

and $\hat{V}(X) = \exp(2\bar{y})\ [\ \psi_n(2V(y)) - \psi_n\left(\left(\frac{n-2}{n-1}\right)V(y)\right)]$.

The formulas for $\hat{E}(X)$ and $\hat{V}(X)$ are estimates of E(X) and V(X), respectively, given in Aitchison, J. and J.A.C. Brown, The Lognormal Distribution, Cambridge University Press, 1963, page 45.

Application

In response to the proposed coil coating and porcelain enameling regulations, the Agency received comments pointing out that permits usually required less than 30 samples to be taken during a month while the monthly average used as the basis for permits and pretreatment requirements usually is based on the average of 30 samples.

In applying the treatment effectiveness values to regulations we have considered the comments, examined the sampling frequency required by many permits and considered the change in values of averages depending on the number of consecutive sampling days in the averages. The most common frequency of sampling required in permits is about ten samples per month or slightly greater than twice weekly. The 99th percentiles of the distribution of averages of ten consecutive sampling days are not substantially different from the 99th percentile of the distribution's 30-day average. (Compared to the one-day maximum, the ten-day average is about 80 percent of the difference between one- and 30-day values). Hence the ten-day average provides a reasonable basis for a monthly average limitation and is typical of the sampling frequency required by existing permits.

The monthly average limitation is to be achieved in all permits and pretreatment standards regardless of the number of samples required to be analyzed and averaged by the permit or the pretreatment authority.

Additional Pollutants

Ten additional pollutant parameters were evaluated to determine the performance of lime and settle treatment systems in removing them from industrial wastewater. Performance data for these parameters is not a part of the CMDB so other data available to the Agency from other categories has been used to determine the long term average performance of lime and settle technology for each pollutant. These data indicate that the concentrations shown in Table VII-15 (page 413) are reliably attainable with hydroxide precipitation and settling. Treatment effectiveness values were calculated by multiplying the mean performance from

Table VII-15 (page 413) by the appropriate variability factor. (The variability factor is the ratio of the value of concern to the mean). The pooled variability factors are: one-day maximum - 4.100; ten-day average - 1.821; and 30-day average - 1.618 these one-, ten-, and thirty-day values are tabulated in Table VII-21 (page 418).

In establishing which data were suitable for use in Table VII-15 two factors were heavily weighed; (1) the nature of the wastewater; and (2) the range of pollutants or pollutant matrix in the raw wastewater. These data have been selected from processes that generate dissolved metals in the wastewater and which are generally free from complexing agents. The pollutant matrix was evaluated by comparing the concentrations of pollutants found in the raw wastewaters with the range of pollutants in the raw wastewaters of the combined metals data set. These data are displayed in Tables VII-16 (page 413) and VII-17 (page 414) and indicate that there is sufficient similarity in the raw wastes to logically assume transferability of the treated pollutant concentrations to the combined metals data base. Battery manufacturing wastewaters also were compared to the wastewaters from plants in categories from which treatment effectiveness values were calculated. The available data on these added pollutants do not allow homogeneity analysis as was performed on the combined metals data base. The data source for each added pollutant is discussed separately.

<u>Antimony</u> <u>(Sb)</u> - The achievable performance for antimony is based on data from a battery and secondary lead plant. Both EPA sampling data and recent permit data (1978-1982) confirm the achievability of 0.7 mg/l in the battery manufacturing wastewater matrix included in the combined data set.

<u>Arsenic</u> <u>(As)</u> - The achievable performance of 0.5 mg/l for arsenic is based on permit data from two nonferrous metals manufacturing plants. The untreated wastewater matrix shown in Table VII-17 (page 414) is comparable with the combined data set matrix.

<u>Beryllium</u> <u>(Be)</u> - The treatability of beryllium is transferred from the nonferrous metals manufacturing industry. The 0.3 mg/l performance is achieved at a beryllium plant with the comparable untreated wastewater matrix shown in Table VII-17.

<u>Mercury</u> <u>(Hg)</u> - The 0.06 mg/l treatability of mercury is based on data from four battery plants. The untreated wastewater matrix at these plants was considered in the combined metals data set.

<u>Selenium</u> <u>(Se)</u> - The 0.30 mg/l treatability of selenium is based on recent permit data from one of the nonferrous metals

manufacturing plants also used for antimony performance. The untreated wastewater matrix for this plant is shown in Table VII-17.

Silver - The treatability of silver is based on a 0.1 mg/l treatability estimate from the inorganic chemicals industry. Additional data supporting a treatability as stringent or more stringent than 0.1 mg/l is also available from seven nonferrous metals manufacturing plants. The untreated wastewater matrix for these plants is comparable and summarized in Table VII-17.

Thallium (Tl) - The 0.50 mg/l treatability for thallium is transferred from the inorganic chemicals industry. Although no untreated wastewater data are available to verify comparability with the combined metals data set plants, no other sources of data for thallium treatability could be identified.

Aluminum (Al) - The 2.24 mg/l treatability of aluminum is based on the mean performance of three aluminum forming plants and one coil coating plant. These plants are from categories included in the combined metals data set, assuring untreated wastewater matrix comparability.

Cobalt (Co) - The 0.05 mg/l treatability is based on nearly complete removal of cobalt at a porcelain enameling plant with a mean untreated wastewater cobalt concentration of 4.31 mg/l. In this case, the analytical detection using aspiration techniques for this pollutant is used as the basis of the treatability. Porcelain enameling was considered in the combined metals data base, assuring untreated wastewater matrix comparability.

Fluoride (F) - The 14.5 mg/l treatability of fluoride is based on the mean performance (216 samples) of an electronics manufacturing plant. The untreated wastewater matrix for this plant shown in Table VII-17 is comparable to the combined metals data set. The fluoride level in the electronics wastewater (760 mg/l) is significantly greater than the fluoride level in raw battery manufacturing wastewater leading to the conclusion that the battery manufacturing wastewater should be no more difficult to treat for fluoride removal than the electronics wastewater. The fluoride level in the CMDB - electroplating data ranges from 1.29 to 70.0 mg/l while the fluoride level in the battery manufacturing wastewater was lower ranging from 0.44 to 3.05 mg/l and leading to the conclusion that the battery manufacturing wastewater should be no more difficult to treat to remove fluoride than electroplating wastewater.

Phosphorus (P) - The 4.08 mg/l treatability of phosphorus is based on the mean of 44 samples including 19 samples from the

Combined Metals Data Base and 25 samples from the electroplating data base. Inclusion of electroplating data with the combined metals data was considered appropriate, since the removal mechanism for phosphorus is a precipitation reaction with calcium rather than hydroxide.

LS&F Performance

Tables VII-18 and VII-19 (pages 415 and 416) 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 a pressure filter, while Plant B uses a rapid sand filter.

Raw wastewater data was collected only occasionally at each facility and the raw wastewater 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-20 (page 417) shows long-term data for zinc and cadmium removal at Plant C, a primary zinc smelter, which operates a LS&F system. This data represents about 4 months (103 data days) taken immediately before the smelter was closed. It has been arranged similarily to Plants A and B for comparison and use.

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 wastewater of plants A and B is high while that for Plant C is low. This results, for plants A and B, in co-precipitation of toxic metals with iron. Precipitation using high-calcium lime for pH control yields the results shown above. Plant operating personnel indicate that this chemical treatment combination (sometimes with polymer assisted coagulation) generally produces better and more consistent metals removal than other combinations of sacrificial metal ions and alkalis.

The LS&F performance data presented here are based on systems that provide polishing filtration after effective L&S treatment. We have previously shown that L&S treatment is equally applicable to wastewaters from the five categories because of the homogeneity of its raw and treated wastewaters, and other factors. Because of the similarity of the wastewaters after L&S treatment, the Agency believes these wastewaters are equally amenable to treatment using polishing filters added to the L&S treatment system. The Agency concludes that LS&F data based on porcelain enameling and nonferrous smelting and refining is directly applicable to the aluminum forming, copper forming, battery manufacturing, coil coating, and metal molding and casting categories, and the canmaking subcategory as well as it is to porcelain enameling and nonferrous melting and refining.

Analysis of Treatment System Effectiveness

Data are presented in Table VII-14 showing the mean, one-day, 10-day, and 30-day values for nine pollutants examined in the L&S combined metals data base. The pooled variability factor for seven metal pollutants (excluding cadmium because of the small number of data points) was determined and is used to estimate one-day, 10-day and 30-day values. (The variability factor is the ratio of the value of concern to the mean: the pooled variability factors are: one-day maximum - 4.100; ten-day average - 1.821; and 30-day average - 1.618.) For values not calculated from the CMDB as previously discussed, the mean value for pollutants shown in Table VII-15 were multiplied by the variability factors to derive the value to obtain the one-, ten- and 30-day values. These are tabulated in Table VII-21.

The treatment effectiveness for sulfide precipitation and filtration has been calculated similarly. Long term average values shown in Table VII-6 (page 407) have been multiplied by the appropriate variability factor to estimate one-day maximum, and ten-day and 30-day average values. Variability factors developed in the combined metals data base were used because the raw wastewaters are identical and the treatment methods are similar as both use chemical precipitation and solids removal to control metals.

LS&F technology data are presented in Tables VII-18 and VII-19. 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 occurred 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 (from a total of about 1300) 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 treated wastewater 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 in common were eliminated by either procedures. Since common engineering practice (mean plus 3 sigma) and logic (treated wastewater concentrations should be less than raw wastewater concentrations) seem to coincide, the data base with the 51 spurious data days eliminated is the basis for all further analysis. Range, mean plus standard deviation and mean plus two standard deviations are shown in Tables VII-18 and VII-19 for Cr, Cu, Ni, Zn and Fe.

The Plant B data was separated into 1979, 1978, and total data base (six years) 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. The largest mean found among the five data sets for each pollutant was selected as the long term mean for LS&F technology and is used as the LS&F mean in Table VII-21.

Plant C data was used as a basis for cadmium removal performance and as a check on the zinc values derived from Plants A and B. The cadmium data is displayed in Table VII-20 (page 417) and is incorporated into Table VII-21 for LS&F. The zinc data was analyzed for compliance with the 1-day and 30-day values in Table VII-21; no zinc value of the 103 data points exceeded the 1-day zinc value of 1.02 mg/l. The 103 data points were separated into blocks of 30 points and averaged. Each of the 3 full 30-day averages was less than the Table VII-21 value of 0.31 mg/l. Additionally, the Plant C raw wastewater pollutant concentrations

(Table VII-20) are well within the range of raw wastewater concentrations of the combined metals data base (Table VII-16), further supporting the conclusion that Plant C wastewater data is compatible with similar data from Plants A and B.

Concentration values for regulatory use are displayed in Table VII-21. Mean one-day, ten-day and 30-day values for L&S for nine pollutants were taken from Table VII-14; the remaining L&S values were developed using the mean values in Table VII-15 and the mean variability factors discussed above.

LS&F mean values for Cd, Cr, Ni, Zn and Fe are derived from plants A, B, and C as discussed above. One-, ten- and thirty-day values are derived by applying the variability factor developed from the pooled data base for the specific pollutant to the mean for that pollutant. Other LS&F values are calculated using the long term average or mean and the appropriate variability factors.

Copper levels achieved at Plants A and B may be lower than generally achievable because of the high iron content and low copper content of the raw wastewaters. Therefore, the mean concentration value from plants A and B achieved is not used; the LS&F mean for copper is derived from the L&S technology.

L&S cyanide mean levels shown in Table VII-8 are ratioed to one-day, ten-day and 30-day 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 cyanide performance was arrived at by using the average metal variability factors. The treatment method used here is cyanide precipitation. Because cyanide precipitation is limited by the same physical processes as the metal precipitation, it is expected that the variabilities will be similar. Therefore, the average of the metal variability factors has been used as a basis for calculating the cyanide one-day, ten-day and thirty-day average treatment effectiveness values.

The filter performance for removing TSS as shown in Table VII-9 (page 409) yields a mean effluent concentration of 2.61 mg/l and calculates to a 10-day average of 4.33, 30-day average of 3.36 mg/l; a one-day maximum of 8.88. These calculated values more than amply support the classic thirty-day and one-day values of 10 mg/l and 15 mg/l, respectively, which are used for LS&F.

Although iron concentrations were decreased in some LS&F operations, some facilities using that treatment introduce iron compounds to aid settling. Therefore, the one-day, ten-day and 30-day values for iron at LS&F were 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.

The removal of additional fluoride by adding polishing filtration is suspect because lime and settle technology removes calcium fluoride to a level near its solubility. The one available data point appears to question the ability of filters to achieve high removals of additional fluoride. The fluoride levels demonstrated for L&S are used as the treatment effectiveness for LS&F.

MINOR TECHNOLOGIES

Several other treatment technologies were considered for possible application in this subcategory. These technologies are presented here.

8. 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 to 1500 m^2/sq m resulting from a large number of internal pores. Pore sizes generally range from 10 to 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-17 (page 443). 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. In Table VII-24, removal levels found at three manufacturing facilities are listed.

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 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-22 (page 419) summarizes the treatment effectiveness for most of the organic priority pollutants by activated carbon as compiled by EPA. Table VII-23 (page 420) 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 use 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 removing and some times recovering 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.

9. 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-18 (page 444).

There are three common types of centrifuges; disc, basket, and conveyor. All three operate by removing solids under the influence of centrifugal force. The fundamental difference among 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, the solids are moved by a screw to the end of the machine, at which point they 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 to 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.

10. 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 to 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 in use at any battery manufacturing facilities.

11. 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. $Cl_2 + NaCN + 2NaOH \text{ ----> } NaCNO + 2NaCl + H_2O$

2. $3Cl_2 + 6NaOH + 2NaCNO \text{ ----> } 2NaHCO_3 + N_2 + 6NaCl + 2H_2O$

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-19 (page 445).

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 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.

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. Alkaline chlorination is also used for cyanide treatment in a number of inorganic chemical facilities producing hydroganic acid and various metal cyanides.

12. 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-20 (page 446).

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:

$$CN^- + O_3 \text{ ----> } CNO^- + O_2$$

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.

13. 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-21 (page 447) 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.

14. 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 to 54°C (120 to 130°F) and the pH is adjusted to 10.5 to 11.8. Formalin (37 percent formaldehyde) is added while the tank is vigorously agitated. After 2 to 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 cyanide-bearing 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.

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.

15. 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-22 (page 448) 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 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. Vacuum evaporation equipment may be classified as submerged tube or climbing film evaporation units.

Another means of increasing energy efficiency is vapor recompression evaporation, which enables heat to be transferred from the condensing water vapor to the evaporating wastewater. Water vapor generated from incoming wastewaters flows to a vapor compressor. The compressed steam than travels through the wastewater via an enclosed tube or coil in which it condenses as heat is transferred to the surrounding solution. In this way, the compressed vapor serves as a heating medium. After condensation, this distillate is drawn off continuously as the clean water stream. The heat contained in the compressed vapor is used to heat the wastewater, and energy costs for system operation are reduced.

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. Wastewater 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. Wastewater 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.

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. Capital costs for vapor compression evaporators are substantially higher than for other types of evaporation equipment. However, the energy costs associated with the operation of a vapor compression evaporator are significantly lower than costs of other evaporator types. 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 corrosive liquids are handled.

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. Vapor compression evaporation has been practically demonstrated in a number of industries, including chemical manufacturing, food processing, pulp and paper, and metal working. One battery plant has recently reported showing the use of evaporation.

16. 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-23 (page 449) 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. Dissolved air flotation is of greatest interest in removing oil from water and is less effective in removing heavier precipitates.

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.

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 wastewater 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. Auxiliary 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 usually 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.

17. 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-24 (page 450) 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.

18. 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.

19. 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-25 (page 451). 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 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 proved 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 solutions. 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 and are displayed in Table VII-25 (page 421). 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.

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 wastewater 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 must usually 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 compartmentalized 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.

20. 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 nongelatinous, 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 toxic 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 Table VII-26 (page 422) 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 in Table VII-26 unless lower levels are present in the influent stream.

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, the 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 to 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.

21. 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.

Table VII-27 (page 422) contains performance figures obtained from pilot plant studies. Peat adsorption was preceded by pH adjustment for precipitation and by clarification.

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.

22. 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-26 (page 452) depicts a reverse osmosis system.

As illustrated in Figure VII-27, (page 453), 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 to 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 caused by 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 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. Downtime for flushing or cleaning is on the order of two 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 wastewater applications in a variety of industries. In addition to these, there are 30 to 40 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.

23. 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-28 (page 454) 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.

<u>Application and Performance</u>. 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.

<u>Advantages and Limitations</u>. 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 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.

24. 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 2 to 8 atm (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-29 (page 455) 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 is 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 test data in Table VII-28 (page 423) indicate ultrafiltration performance (note that UF is not intended to remove dissolved solids).

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 quired 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 occasionally necessary to 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.

25. 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-30 (page 456).

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.

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 wastewater 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 at least two battery manufacturing plants for sludge dewatering.

26. Permanganate Oxidation

Permanganate oxidation is a chemical reaction by which wastewater pollutants can be oxidized. When the reaction is carried to completion, the byproducts of the oxidation are not environmentally harmful. A large number of pollutants can be practically oxidized by permanganate, including cyanides, hydrogen sulfide, and phenol. In addition, the chemical oxygen demand (COD) and many odors in wastewaters and sludges can be significantly reduced by permanganate oxidation carried to its end point. Potassium permanganate can be added to wastewater in either dry or slurry form. The oxidation occurs optimally in the 8 to 9 pH range. As an example of the permanganate oxidation process, the following chemical equation shows the oxidation of phenol by potassium permanganate:

$$3\ C_6H_5(OH) + 28KMnO_4 + 5H_2 \text{ ----> } 18\ CO_2 + 28KOH + 28\ MnO_2.$$

One of the byproducts of this oxidation is manganese dioxide (MnO_2), which occurs as a relatively stable hydrous colloid usually having a negative charge. These properties, in addition to its large surface area, enable manganese dioxide to act as a sorbent for metal cation, thus enhancing their removal from the wastewater.

Application and Performance. Commercial use of permanganate oxidation has been primarily for the control of phenol and waste odors. Several municipal waste treatment facilities report that initial hydrogen sulfide concentrations (causing serious odor problems) as high as 100 mg/l have been reduced to zero through the application of potassium permanganate. A variety of industries (including metal finishers and agricultural chemical manufacturers) have used permanganate oxidation to totally destroy phenol in their wastewaters.

Advantages and Limitations. Permanganate oxidation has several advantages as a wastewater treatment technique. Handling and storage are facilitated by its non-toxic and non-corrosive nature. Performance has been proved in a number of municipal and industrial applications. The tendency of the manganese dioxide by-product to act as a coagulant aid is a distinct advantage over other types of chemical treatment.

The cost of permanganate oxidation treatment can be limiting where very large dosages are required to oxidize wastewater pollutants. In addition, care must be taken in storage to prevent exposure to intense heat, acids, or reducing agents; exposure could create a fire hazard or cause explosions. Of greatest concern is the environmental hazard which the use of manganese chemicals in treatment could cause. Care must be taken to remove the manganese from treated water before discharge.

Operational Factors. Reliability: Maintenance consists of periodic sludge removal and cleaning of pump feed lines. Frequency of maintenance is dependent on wastewater characteristics.

Solid Waste Aspects: Sludge is generated by the process where the manganese dioxide byproduct tends to act as a coagulant aid. The sludge from permanganate oxidation can be collected and handled by standard sludge treatment and processing equipment. No battery manufacturing facilities are known to use permanganate oxidation for wastewater treatment at this time.

Demonstration Status. The oxidation of wastewater pollutants by potassium permanganate is a proven treatment process in several types of industries. It has been shown effective in treating a wide variety of pollutants in both municipal and industrial wastes.

IN-PROCESS POLLUTION CONTROL TECHNIQUES

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 reducing the volume of wastewater to treatment as more concentrated waste streams from which the pollutants 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 in reduced water consumption, 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-29 (Page 424) shows, some in-process control measures have been implemented by many battery manufacturing facilities. The wide range of 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 wastewater control at these facilities.

Many in-process pollution control techniques are of a general character, although specific applications of these techniques vary among different battery manufacturing subcategories. Some of the available 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 wastewater 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, wastewater segregation is frequently a prerequisite for the extensive practice of wastewater recycle or reuse.

Wastewater Segregation - The segregation of wastewater streams is a key element in implementing effective pollution control for plants in the lead subcategory. Segregation is implemented to separate streams of widely varying physical and chemical characteristics for subsequent reuse, discharge, or treatment. This is done to prevent dilution of the process wastewaters and also to maintain the character of the nonprocess stream for reuse or discharge. The cumulative effect of segregation is to reduce treatment costs and increase pollutant removal.

The specific effects of commingling process wastewater with nonprocess wastewater is to increase the total volume of process wastewater to be treated. This has an adverse effect on both treatment performance and cost. The increased volume of wastewater increases the size and, therefore, cost of wastewater treatment facilities. Since a given treatment technology has a specific treatment effectiveness and can only achieve certain discharge concentrations of pollutants, the total mass of pollutants which is discharged increases with dilution. Thus, a plant which segregates noncontact cooling water and other nonprocess waters from process wastewater will almost always achieve a lower mass discharge of pollutants while substantially reducing treatment costs.

Lead battery manufacturing plants commonly produce multiple process and nonprocess wastewater streams. The identified nonprocess streams include wastewater streams that are reuseable after minimal treatment and other streams that are not reusable. Reuseable waters are most often noncontact cooling waters. This water is uncontaminated and can be recycled in a closed indirect cooling configuration as well as used as makeup for process water using operations. Noncontact cooling water is commonly recycled for reuse in lead battery plants.

The segregation of dilute process waste streams from those bearing high lead loadings may allow further use of the dilute streams. Sometimes the lightly polluted stream may be recycled to the process from which they were discharged, such as in lead strip casting. Other waste streams may be suitable for use in another process with only minimal treatment, such as the use of humidity curing water in paste machine washdown. Selected dilute process waste streams are suitable for incorporation into the product, such as the use of battery rinse water in acid cutting.

Segregation of wastewater streams may allow lower cost, and separate treatment of the streams. For example, wastewater streams containing high levels of suspended solids may be treated in separate inexpensive settling systems rather than more expensive lime and settle treatment. 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 selected wastewater streams may yield an additional economic benefit to the plant by promoting recovery of process materials. The solids borne by wastewater from a specific process operation are primarily composed of materials used in that operation. These sludges resulting from separate settling of these streams may be reclaimed for use in the process with little or no processing or recovered for reprocessing. For example, this technique presently is used to recover lead used in processing pasted plates at lead battery manufacturing plants.

Certain nonprocess wastewater streams are not usually reused due to the nature of the stream or operation. At lead subcategory plants, these streams include discharges from water softener and deionizer backflushes, cooling tower and boiler water blowdowns, and regular production employee showers and other sanitary waters. Segregation and separate discharge of these streams is commonly observed in lead subcategory plants.

Wastewater Recycle and Reuse - The recycle or reuse of process wastewater is a particularly effective technique for the reduction of both pollutant discharges and treatment costs. The term "recycle" is used to designate the return of process wastewater usually after some treatment 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 discharges, product rinsing and wastewater from equipment and area cleaning. Numerous other process wastewater streams from lead battery manufacturing activities may also be recycled or reused. Common points of wastewater recycle in present practice include air pollution control scrubbers, equipment and area washdown, some product rinsing operations and contact cooling.

Both recycle and reuse are frequently possible without extensive treatment of the wastewater; process pollutants present in the waste 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 expense and complications because the required treatment is often minimal and the water for recycle is immediately available. As an example, pasting area washdown water can be collected in the immediate area of pasting, settled and the supernatant reused for washdown of the pasting area.

The rate of water used in wet air 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 can 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 may be 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 the 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 or closed heat exchangers 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 levels of contaminants in these high volume waste streams are usually 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 increasing concentrations of dissolved solids in the water. The buildup of dissolved salts generally necessitates some small discharge or "blowdown" from the process to treatment. In those cases, where the rate of addition of dissolved salts is balanced by removal of dissolved solids in water entrained in settled solids, complete recycle with no discharge can be achieved. In other instances, the contaminants which build up in the recycle loop may be compatible with another process operation, and the "blowdown" may be used in another process. Examples of this condition are observed in lead subcategory scrubbers, 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.

<u>Water Use Reduction</u> - The volume of wastewater discharge from a plant or specific process operation may be reduced by simply 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 substantial 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 plants 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 involving the human factor have been found to be somewhat unreliable in practice; production personnel often fail to turn off manual valves when production units are shut down and tend 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 plant where the daily average production normalized discharge flow rate 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 in this category at essentially no cost. (A net saving may be realized from the reduced cost of water and sewage charges). Additional flow reductions may be achieved by the implementation of more effective water use in some process operations.

Rinsing is a common operation in the manufacture of batteries and a major source of wastewater discharge at most plants. Efficient rinsing requires the removal of the greatest possible mass of material in the smallest possible 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 longer product residence times and high mixing rates in rinses.) Rinsing efficiency is also increased by the use of multi-stage and countercurrent cascade rinses. Multi-stage rinses reduce the total rinse water requirements by allowing the removal of much of the contaminant in a more concentrated rinse with only the final stage rinse diluted to the levels required for final product cleanliness. In a countercurrent cascade 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. The technical aspects of countercurrent cascade rinsing are detailed in the following subsection.

Equipment and area cleanup practices observed at battery manufacturing plants vary widely. While some plants employ completely dry cleanup techniques, many 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 vacuum pick up floor wash machines and bucket and sponge or bucket and mop techniques as observed at some plants.

A major factor contributing in many cases to the need for battery washing is electrolyte spillage on the battery case during filling. This spillage and subsequent battery washing requirement is maximized when batteries are filled by immersion or by "overfill and withdraw" techniques. 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.

Countercurrent Cascade Rinsing and Multi-Stage Rinsing

Of the many schemes discussed above for reduction of water use in a battery production plant, countercurrent cascade rinsing is most likely to result in the greatest reduction of water consumption and use.

Countercurrent cascade rinses are employed at many plants in the battery manufacturing category. In most cases, however, these techniques are not combined with effective flow control, and the wastewater discharge volumes from the countercurrent cascade rinses are as large as or larger than corresponding single stage rinse flows at other plants. Three instances of countercurrent cascade rinsing with reasonable levels of flow control are noted to illustrate the benefits achievable by this technique within the battery manufacturing category.

Two lead subcategory plants use two-stage countercurrent cascade rinses to rinse electrodes after open-case formation. These rinses discharge 3.3 and 3.6 l/kg. At 28 other plants, single stage rinses are used after open-case formation with an average discharge of 20.9 l/kg. Thus, the use of two-stage countercurrent cascade rinsing in this application is seen to reduce rinse wastewater flow by a factor of 6.05 (83% flow reduction). Still further reductions would result from better operation of these rinse installations or from the use of additional countercurrent cascade rinse stages.

Rinse water requirements and the benefits of countercurrent cascade rinsing may be influenced by the volume of drag-out solution carried into each rinse stage by the electrode or material being rinsed, by the number of rinse stages used, by the initial concentrations of impurities being removed, and by the final product cleanliness required. The influence of these factors is expressed in the rinsing equation which may be stated simply as:

$$Vr = \left[\frac{Co}{Cf}\right]^{(1/n)} \times VD$$

Vr is the flow through each rinse stage.

Co is the concentration of the contaminant(s) in the initial process bath

Cf is the concentration of the contaminant(s) in the final rinse to give acceptable product cleanliness

n is the number of rinse stages employed,

and

VD is the flow of drag-out carried into each rinse stage

Drag-out is solution which remains in the pores and on the surface of electrodes or materials being rinsed when they are removed from process baths or rinses. In battery manufacturing, drag-out volumes may be quite high because the high porosity and surface areas of electrodes. Based on porosity and surface characteristics, it is estimated that the drag-out volume will be approximately 20 percent of the apparent electrode volume (including pores). Because of the highly porous nature of many electrodes, perfect mixing in each rinse generally is not achieved, and deviation from ideal rinsing is anticipated.

The application of the rinsing equation with these considerations to the lead subcategory example cited above provides a basis for the transfer of countercurrent rinse performance to other subcategories and process elements. Based on the specific gravities of component materials and approximately 20 percent porosity, the apparent specific gravity of lead electrodes may be estimated as 7.0; the volume of drag-out per unit weight of lead is therefore:

$$VD = \frac{0.2}{7.0} = 0.029 \text{ l/kg.}$$

Based on the average single stage rinse flow, the rinse ratio (equal to Co/Cf) is:

$$\frac{Co}{Cf}\left(^{1}/_{1}\right) = \frac{Vr}{VD} = \frac{20.9}{0.029} = 720$$

The calculated flow for a two stage countercurrent rinse providing equivalent product cleaning is then given by

$$Vr = \frac{Co}{Cf}\left(^{1}/n\right) \times Vd = 720^{0.5} \times 0.029 = 0.78 \text{ l/kg.}$$

This calculated flow yields a rinse ratio of 26.8 and is 4.4 times (26.8 ÷ 6.05) lower than the observed countercurrent rinse flow reflecting the extent to which ideal mixing is not achieved in the rinses. One of these two plants was visited for sampling and was observed to employ no mixing or agitation in the rinse tanks. Therefore, performance significantly closer to the ideal should be attainable simply by adding agitation to the rinse tanks.

To transfer countercurrent rinse results to other process elements, allowance must be made for the fact that required rinse ratios may be substantially different in order to provide adequate contaminant removal from some electrodes. To encompass all process element requirements, an extreme case is considered in which contaminants initially prasent at 10 percent (100,000 mg/l) in a process bath must be reduced to a nearly immeasurable 1.0 mg/kg (one part per million) in the final rinsed electrode. The 20 percent drag-out found appropriate for lead electrodes is also applicable to other electrode types and materials rinsed, since all have high porosity and surface area requirements in order to sustain high current densities. The specific gravities of most electrode materials are lower than those of lead and its salts. Consequently, lower electrode densities are expected. An estimated specific gravity of 4.5 is used for purposes of this calculation. Also, the active materials used as the basis of most production normalizing parameters except lead make up only approximately 45 percent of the total electroda saicht.

On the basis of these figures, it may be calculated that the volume of drag-out amounts to:

$$VD = \frac{0.2}{4.5} = 0.044 \text{ l/kg of electrode}$$

or

$$VD = \frac{0.2}{4.5} \times \frac{1}{0.45} = 0.1 \text{ l/kg of pnp}$$

The concentration of pollutant in the final rinse may be calculated as 10 mg/l based on the factors postulated and calculated above. The rinse ratio (Co/Cf) is 10,000.

Multi-stage rinsing uses two or more stages of rinsinc each of shich is supplied with fresh water and discharges to sewer or treatment. For a multi-stage rinse, the total volume of rinse wastewater is equal to n times Vr while for a countercurrent rinse, Vr is the total volume of wastewater discharge.

Using these rinsing parameters, theoretical rinse flow requirements may be calculated for single stage rinses and for a variety of multi-stage and countercurrent rinses. Both ideal flows and flows increased by the 4.4 factor found in the lead subcategory are shown for countercurrent rinses.

Number of Rinse Stages	Required Rinse Water per Mass of Product (pnp) (l/kg)			
	Multi-stage	Countercurrent		
	Ideal	Ideal	Adjusted	Rinse Ratio
1	1000	1000	-	
2	20	10	44.0	22.7
3	6.6	2.2	9.68	103.3
4	4.0	1.0	4.4	227.3
5	3.2	0.63	2.77	361.
7	2.6	0.37	1.63	613.
10	2.5	0.25	1.1	909.

Single stage rinse flow requirements calculated for these conditions are somewhat higher than those presently observed in the battery manufacturing category. The highest reported rinse flow is approximately 2000 l/kg, and most are substantially less than 1000 l/kg. This indicates that the cleanliness level has been conservatively estimated.

In general, these calculations confirm that extreme conditions have been chosen for the calculations and that the lead subcategory data have been transferred to rinsing requirements more severe in terms of drag-out and cleanliness than any presently encountered in practice. Therefore, countercurrent rinse discharge flows lower than those calculated should be attainable in all process elements in the category.

In later sections of this document it is necessary to calculate the wastewater generation when countercurrent cascade rinsing is substituted for single stage rinsing. A rinse ratio of 6.6 is used later for this calculation. It is based on the 6.05 rinse ratio found in existing lead subcategory plants with an allowance of 10 percent added for increased efficiency obtained by improved agitation. As shown above, a rinse ratio of 22 would be expected from a two stage system and much higher ratios are obtained by using additional stages.

Lead Subcategory Process Element In-Process Control Techniques

In this subcategory, some in-process control technologies which significantly reduce pollutant discharge are commonly practiced and are consequently included in BPT technology. Other techniques are included in the BAT technology. Some of these control technologies are discussed below.

Process water uses in lead subcategory plants include leady oxide production, paste preparation and applications, grid manufacture (including mold release preparation and direct chill casting), plate (electrode) curing, plate or battery formation, plate soak, battery wash, floor wash, wet air pollution control, battery repair, laboratory, truck wash, handwash, respirator wash, and laundry. The following discussions address waste segregation, recycle and reuse, and other process modifications in the lead subcategory process elements which will reduce the generation of process wastewater.

Leady Oxide Production - Leady oxide is produced either in a ball mill or by the Barton process. The Barton process does not generate process wastewater, but uses noncontact cooling water for certain mechanical portions of the process. Surface cooling of ball mills does, however, generate wastewater because the water is contaminated by lead particles scrubbed from the ambient air. Process change can eliminate this process wastewater by several alternative procedures. The first alternative is to shut off the cooling water entirely, as the ball mills are observed to be operated without cooling water. A second alternative is to use internal cooling. This is accomplished by the closely controlled injection (spray) of water into the open end of the ball mill. The cooling water is evaporated in the ball mill and passes out as water vapor through the baghouse which collects lead dust. Another alternative is to install water recirculation equipment for shell cooling if this method of cooling is considered to be necessary. This would require the installation of a water collection device, piping for return water to the ball mill, and a pump. Still an additional alternative is to cool only the trunion bearings of the ball mill, allowing the ball mill to be operated at a higher temperature and production rate. This alternative requires a small amount of noncontact process wastewater which can be recirculated or routed directly to discharge.

Maintenance practices are observed to be important in eliminating unnecessary leaks in ball mill cooling which would generate contamination of noncontact cooling water. One lead subcategory plant was observed to have a leaking ball mill cooling jacket resulting in increased volume of water to be treated and loss of leady oxide material.

Good housekeeping practices are also important in leady oxide production. Reduction in spillage in bulk handling can be achieved using dust control and rapid dry cleanup of spilled materials.

Grid Manufacture - Grid Manufacture includes grid casting (making battery plate grids in a die casting type machine), connectors and tabs (parts) casting, continuous strip (direct chill or DC) casting of lead, lead rolling and mold release formulation. Melting furnaces are used to melt the lead, scrubbers or baghouses are sometimes used to control lead fumes, and mold releases are often compounded on site at battery manufacturing plants. Lead casting was performed at 32 of the 34 sites visited before and after proposal.

Both grid casting and small parts casting are performed by cooling molten lead in dies, or molds. Cooling water is used to cool the lead indirectly by passing the water through the mold without contacting the lead itself. Many plants recirculate this cooling water in a closed loop system. Some plants use a glycol indirect heat exchanger as part of their closed cooling system which generates neither process nor nonprocess wastewaters.

Grid casting requires the use of mold release compounds which prevent the molten lead from adhering to the mold surface. Mold release compound can either be purchased or formulated on-site; most plants formulate the compound on-site. Commercial mold releases (both cork-kerosene and silica-silicon oil based formulations) are available. Process wastewater is generated from mold release formulation by cleaning equipment after mixing batches of the release material. No specific technology for reducing the wastewater generated in mold release formulation has been identified.

Direct chill lead casting uses a process which continuously melts lead ingots, draws the solidifying molten lead through a die and sprays the die and lead strip directly with cooling water to cool and solidify the continuous strip. This strip is fed to a rolling mill for forming. The contact cooling water is continuously recirculated with only an occassional (semi-annual) blowdown to wastewater treatment. No further flow reduction techniques have been identified. An oil emulsion is used for lubrication during lead rolling. This emulsion is contract hauled to offsite land disposal by all plants which perform lead rolling in conjunction with battery manufacturing.

Melting pots are used by all plants which perform grid manufacture. This operation only generates a wastewater from wet air scrubbers. Flow reduction for air scrubbers are discussed below.

<u>Pasting</u> - 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 is removed from the recirculation system with the settled solids and by evaporation resulting in a negative water balance and requiring the introduction of fresh make-up water. Water from the recirculated wash-down stream is sometimes used in the paste mixing operation and ultimately is evaporated from the plates in drying and curing. Fifty-seven plants in the subcategory reported zero discharge of pasting area wastewater. In addition, solids recovery is practiced at many plants by reusing the settled solids in the paste mix or shipping the solids to a smelter.

<u>Curing</u> - Curing may be performed by stacking plates with ambient curing, the use of controlled temperature and humidity rooms, or by the use of steam chests. Discharges have been observed from both humidity-controlled and steam curing operations. Discharge flow control methods have also been observed. Flow reduction or elimination techniques are discussed below for each curing method.

<u>Humidity curing</u> ovens sometimes generate a process wastewater discharge. This discharge may be eliminated by the use of a variety of design alternatives. A vendor of humidity-controlled ovens maintains that these ovens may be operated in either a dry or wet mode and still produce high quality cured plates. The dry mode eliminates any need for water and allows the use of existing equipment for curing.

Internal recirculation of spray water can be used to eliminate the discharge of wastewater from the wet mode of operation. Elevated temperatures (100-210°F) result in the loss of water vapor requiring makeup to the internal collection area. To eliminate problems with spray nozzle plugging, various in-line filtration devices and nozzles can be used to screen out or pass particles. Extended operation of this recirculation system may result in the accumulation of leady oxide particles in the collection area. This material may be periodically collected for reclaim at a smelter. Membrane evaporation (simultaneously passing air through and water across a coarse membrane or cloth) is also used for water distribution. This method precludes the need for filtration since spray nozzles are not used.

Drainage water from the humidity oven may be directed to the pasting area as makeup water for equipment and floor washdown. Some plants keep their pasting area floors continuously wet to suppress lead dust. This practice evaporates large amounts of water and can readily accomodate the typical 14 gph flow from a curing oven.

All of the water reuse and discharge reduction techniques outlined above have been observed at visited battery plants. Other techniques used to humidify air or combinations of these can be adapted to eliminate discharge from humidity curing ovens.

Another approach is to use an external water recycle design configuration. Drainage water from the curing oven is collected in a trench at the base of the oven, pumped to a holding tank with a level control, and is subsequently returned to the spray nozzles. Settling in the holding tank plus in-line filtration is used to prevent nozzle plugging.

Steam curing is done by some plants which achieve faster plate curing by the direct impingment of steam on the plates. In this process, steam condenses on the electrodes producing a 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.

There are also a number of alternative ways to maintain the use of steam curing and still achieve zero discharge from this operation. Existing steam curing designs generally employ a water sealed chest. The steam injected into the chest is subsequently vented to the plant atmosphere. In this manner, the temperature (and humidity) is controlled in the chest by virtue of the steam addition rate and steam properties (temperature and pressure).

This discharge flow may be avoided altogether by the use of electric heaters submerged in water-filled troughs inside the steam chest. Condensed steam is then internally recirculated back to the trough for re-evaporization. Variation of temperature and relative humidity can be achieved by varying the wattage employed in the heating elements. As a similar alternative, steam can be used as the heating medium for the curing oven humidification water. Once again, with internal recirculation of condensed steam, no discharge need be incurred.

Closed Formation (In-Case) - Closed formation comprises three process elements: single fill, double fill, and fill and dump. The wastewaters from each of these elements are similar. The principal wastewater sources are (1) electrolyte spills, (2) battery case product rinse water, (3) floor area and equipment washdown, and (4) contact cooling of battery cases during rapid formation. The type of formation process primarily impacts the need for battery rinsing and area equipment washdown. Spills are controllable by proper filling procedures and good housekeeping; area washdown water can be treated and recycled; battery rinsing can be minimized and reused; contact cooling water can be recycled or obviated by process modification. Each of these control techniques as well as other in-process techniques which impact closed formation are discussed below.

Spills - Electrolyte spills can be greatly reduced or eliminated by the use of proper filling techniques, such as automatic or vacuum controlled filling rather than overfill and withdraw. Also, unavoidable spills can be collected, segregated, and reused in acid cutting. This practice is performed in a number of lead subcategory plants.

Product Rinsing - Product rinsing is observed predominately at plants where immersion filling techniques are used. Flow elimination is achieved by minimization of water use in the rinsing station followed by reuse of the rinse in acid cutting. These operations are discussed in more detail in the discussions of battery washing.

Equipment and Other Area Washdown - Floor area washdown water can be minimized by the efficient use of power (vacuum pick up) floor scrubbing techniques. Water volume reduction may be achieved by proper maintenance of floors to minimize cracks and pores in which spilled materials may lodge. Treated wastewater can be used in floor wash hoses in the formation and other plant areas. This technique was observed during site visits.

Contact Cooling Water - The formation process generates heat which must be removed from the batteries being formed if acceptable product quality is to be achieved. The rate at which this heat is generated depends upon the charge rate (amperage) and the size of the battery; the rate of heat accumulation is a function of generation rate, area available for dissipation and the medium used for heat transfer from the electrolyte. When batteries are formed rapidly as is practiced in some plants, heat generation is so rapid that the batteries must be cooled using water on the battery cases. This has been observed for both small (SLI) and large (industrial) batteries. This contact cooling water constitutes a significant source of wastewater discharge at these plants.

Flow reduction or elimination of contact cooling water during formation can be achieved in a number of ways. The water can be extensively recycled with a small bleed stream removed to maintain a tolerable contaminant level. The charging rate can be altered to eliminate the need for cooling water by slow charging, or the use of controlled charging techniques.

Extensive recycling of cooling water is practiced at one plant visited. To dissipate heat, a "cooling tank" is used in the area where the cooling takes place. Other techniques are used as well, such as the addition of caustic to maintain a safe operable pH range. To control metal (e.g., iron) contamination, a water softener is used to treat a small portion of the recycled water. The buildup of iron, which presumably stains battery cases, can also be avoided by the use of epoxy coatings on racks or conveyors to eliminate corrosion, and control of contact cooling water flow patterns. Ultimately the recycle water bleed stream can be used in acid cutting, pasting area washdown, or as makeup to the battery wash system.

Slow or Controlled Formation - A number of closed formation techniques are used in lead battery plants which eliminate the need for cooling water during formation. Some of these techniques allow for forming to take place at an overall rate equal to or less than that rate which utilizes cooling water. These practices include (1) slow rate formation, (2) controlled charge rate formation, (3) air cooling, and (4) use of chilled acid. At some plants, a combination of these practices is applied, such as controlled charging in tunnels with air cooling. The convective passage of air over batteries during formation has been observed to serve as a mechanism to convey acid fumes to an air scrubber as well as for heat dissipation.

The primary reduction in heat accumulation and maintenance of a lower product temperature is due to charging rate control. When batteries are charged more slowly, the heat is dissipated to the atmosphere without the need for contact cooling water. Formation at a lower rate reduces gassing during formation and consequently reduces acid load on wet air pollution control scrubbers as well as the extent of acid contamination of battery cases and formation areas and equipment. The additional heat generated during rapid, uncontrolled formation is a direct result of the inefficient conversion of electrical energy to heat as opposed to chemical reaction. Slow, controlled formation will require less overall energy input to form a battery.

The term slow formation denotes a charging rate such that the heat generated is adequately dissipated without cooling water and the battery temperature is maintained so that battery quality is not adversely affected. It does not require a specific forming time. Observations made during site visits demonstrate that batteries can be formed in much less than 24 hours using a combination of these techniques.

Controlled charging denotes the use of current variation during the course of formation to maintain acceptable electrolyte temperature. Current variation is achieved manually, by use of automatic timing or small computer devices. Controlled charging was observed at five sites. Overall controlled charging (formation) times varied at the plants visited (for a given product type) from 9 hours to a total of 72 hours. The latter time has an associated maximum charge rate of 4 amps for 30 hours.

It was observed during site visits that batteries formed at lower rates were predominantly stacked on stationary racks as opposed to conveyors. It was stated at proposal that more floor area would be required for slow formation which could last up to seven days. Based on information gathered, it is feasible for slow or controlled-charge formation to be achieved in much less time and without the need for additional building space. Concerning additional building space requirements, several factors may be considered as follow:

(1) At sites where conveyors are used, they were observed to have sufficient additional floor space to add stationary racks to handle any additional in-process inventory where slow forming is instituted.

(2) If a site already uses racks and maintains that there is no additional floor space available for more racks, then racks with additional levels can be used. It was observed that charging racks (for trickle charging) have been used with as many as 15 batteries stacked vertically. More usually, batteries are stacked in racks four to six batteries high.

(3) Based on observed practices, it is unlikely that formation duration would need to be increased by more than about 50 percent if the current operation at a site uses as long as 24 hours. It is possible that no increase be incurred at all if the appropriate technology is used. However, any anticipated increase in in-process inventory can easily be handled by existing building space.

Contact with vendors of rectification equipment confirms the feasibility of using existing rectifiers for slow charging by reconfiguring the charging circuits.

Plant Water Balance - Several closed formation procedures are employed in the production of wet and damp charged batteries (single fill, double fill, and fill and dump) resulting in significant variations in wastewater discharge flow rate. In addition to the difference between wet and damp charged 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 charged 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 of 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 needed in acid cutting and therefore the potential amount of process wastewater which may be used in battery acid cutting.

Closed formation 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.

Open Formation - Open formation is performed by charging plates in open tanks of electrolyte. These plates may then also be assembled and placed into cases followed by filling the case with electrolyte for shipping; this is open wet formation. Open dehydrated formation requires rinsing and drying the charged plates prior to assembly and shipping.

Both open wet and open dehydrated formations incur the same potential sources of wastewater during formation: electrolyte spills, area and equipment washdown, and electrolyte dumping. Electrolyte spills can be reduced or avoided by careful filling; this will also result in a reduced need for area washdown water. As in closed formation, spill collection mechanisms can be instituted such as catch trays beneath the forming table which direct the spills to a common collection tank.

As in closed formation, area washdown which is usually performed with hoses can utilize treated wastewater. Equipment washdown can also be performed with treated wastewater; one plant visited performed both functions with treated wastewater.

Open formation electrolyte is dumped periodically after a specified number of formation cycles are performed. Some plants were observed to reuse this acid in wet battery filling and boost charging which would eliminate the discharge.

In addition to the above sources of wastewater, dehydrated plate formation generates wastewater from plate rinsing and from plate dehydrating. Some plants also rinse plates after open wet formation, however, the flows from these rinsing operations are substantially lower than flows from open dehydrated formation plate rinsing. Thorough rinsing is required in open dehydrated formation to remove residual sulfuric acid from the formed plates and this operation 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 the water seals of vacuum pumps used for the same purpose.

Plate rinse water is generally the major source of wastewater from a lead battery plant making dehydrated batteries. This flow can be reduced by the use of countercurrent cascade rinsing techniques discussed earlier in this section. Currently, plants vary widely in rinsing techniques, from single step continuous flowing rinses to multiple stage countercurrent rinsing. Plate rinse water use can be substantially reduced or even eliminated by using treated wastewater as was done at one plant visited.

Wastewater from vacuum pump seals and ejectors used in dehydrating formed plates for use in dry charged 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.

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 dry-charged plates was observed, and approximately 85 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, as observed at one site visited.

Plate Soaking - Plate soaking is an operation which is performed after curing and prior to formation in order to enhance lead oxide sulfation and to allow the heat of sulfation to be dissipated before charging or formation is begun. This is generally performed on thick battery plates approximately 0.25 cm (0.10 inch) as opposed to thinner battery plates. Plates are soaked in an open tank of acid which must be replaced periodically. Discharges from this operation may include spills, area hosedown, tank cleaning, and acid dumping.

As in open formation, careful loading and draining of the soaked plates will minimize spills as well as the need for hosedown water. Hosedown water and tank cleaning can be treated wastewater, thus eliminating any additional discharge. Acid dumping to treatment should only occur when the product mix at the plant will not allow its use in other products and after extensive reuse.

Battery Washing and Rinsing - Battery washing is the water using activity associated with preparation of the battery for shipping. Battery washing may be performed using a detergent or using water only. Battery washing using water only is performed primarily to remove sulfuric acid spilled on the outside of the battery case while washing (using a detergent) is used to remove acid, oil and grease and other soil. Battery rinsing with water also has been observed to be used as part of the forming operations (sometimes referred to as product rinse) to remove the acid from immersing or overfilling the battery or dumping electrolyte from the battery. The wastewater from rinsing the batteries contains acid, lead, and other contaminants from process conveyors, racks, or floors over which the acidic water has contacted.

Reduction or elimination of the wastewater generated by battery washing or rinsing may be accomplished by using manufacturing processes which require less cleaning of the battery case, by reducing the water used for washing or rinsing, and by reusing some or all of the water used for washing or rinsing. Batteries can be filled manually, automatically or semi-automatically with vacuum type injection filling devices which fill the battery to the correct level. Well operated injection filling methods do not require immediate rinsing.

Immersion filling (immersing the batteries in a vat of electrolyte) results in the battery case being heavily contaminated with acid and requires rinsing. Immersion filling is used by about one third of the visited plants and for all types of closed formation. Where double fill formation is used, some plants use injection filling initially and immersion for the second fill with a rinse associated only with the immersion fill. Where immersion filling is performed twice, the batteries are rinsed twice.

From site visits, about twice as many operations use an injection filling method as opposed to immersion. All plants which have a rinse associated with filling and formation use only water so as not to contaminate the electrolyte with detergent when immersed. The water from rinsing after filling, or topping off (an additional filling step sometimes used to ensure the proper electrolyte level), can be controlled and reused in other manufacturing processes. Some plants with immersion filling do not recycle the water at the rinsing station. This could be achieved by installation of a small tank and some return piping to the spray nozzles. Overflow is then collected in a holdup tank until acid cutting operations are performed - usually about once a week. This requires a tank and overhead piping to the acid cutting area.

Samples taken at one site, demonstrated that most metal concentrations were well below engineering specifications for acid cutting water. Metals present at concentrations above engineering specifications can be chemically removed or diluted to suitable concentrations with fresh water. If the mechanisms discussed below for minimizing water use in rinsing are implemented, all of the diluted rinse water can be reused in acid cutting. In the case of rinsing after filling, continuous makeup of water to the rinse cycle serves to only dilute the electrolyte being rinsed off. Therefore, for rinsing operations in the formation area the overflow should be suitable for acid cutting. The required holdup period of about a week would also provide plant personnel time to assay the chemical species of concern in two collected rinse waters prior to using each batch of water for acid cutting.

The primary mechanisms for minimizing water use in rinsing are:

(1) Use of a switching device (mechanical or electronic) to stop the flow of water to the spray nozzles when batteries are not actually being rinsed. This practice was observed at several plants visited.

(2) Use of the appropriate types of spray nozzles to properly disperse the rinse water.

(3) Use of recycle at the rinse stations and overflow to a collection tank for water reuse.

Some plants were found to run water continuously through spray nozzles and some do not use spray nozzles. One plant discharges rinse water to the on-site wastewater treatment system after the volume necessary for acid cutting is fulfilled. This plant did not employ a recycle mechanism and used an excessive amount of water for rinsing.

The mechanisms for recycle, segregation, and reuse of battery rinse water as a finishing step are the same as those described above for battery rinsing after filling operations. Usually smaller battery products, such as SLI batteries are washed automatically in a conveyor spray mechanism. Industrial and specialty batteries are generally hosed down by hand prior to finishing since they are produced in smaller numbers than the SLI batteries. Water recirculation and reuse can be instituted in hand washing or using stations similarly to those described for automatic or machine washing.

Five visited plants use detergent wash systems with automatic spray washers. Some washing lines comprise an initial water rinse to remove acid, then a detergent wash, and a final water rinse; others do not include the initial water rinse.

Segregation and reuse of initial battery rinse water is feasible for the automatic detergent washer system. This can be done using recycle and collection systems for routing the water to acid cutting. Water contaminated with detergent has been reported by lead battery manufacturers to be unsuitable for process-related reuse. Water use can be minimized, however, by using the final rinse as makeup to the detergent portion of the system.

Some lead battery manufacturing operations do not use battery washing or rinsing procedures. This largely stems from two conditions; (1) the plant utilizes extensive contact cooling during closed forming operations which acts as a rinsing operation, or (2) dehydrated batteries are produced. Some plants use dry battery production techniques and still maintain a washing operation.

<u>Floorwash</u> - Floor washing procedures include the use of hoses for general area washdown, buckets and mops for miscellaneous cleanup, and power (vacuum) scrubbers for general plant floor area cleanup.

To achieve minimization of floor wash pollutant discharge the following measures can be taken:

(1) settle power scrubber solids prior to treatment; this water has been assayed to contain high concentrations of suspended lead

(2) dry vacuum major dry spills such as in the leady oxide production area, or pasting area. This has been observed during one site visit

(3) use treated wastewater in hoses for general washdown

Wet Air Pollution Control - Wet air pollution control (WAPC) devices are reported to be used in lead battery plants to varying degrees in the following process activities: leady oxide production, grid manufacture, pasting, formation, battery assembly, battery washing, boost charging, acid mixing, painting (of cases) and laboratories.

The scrubbers reported for battery washing and acid mixing are at sites associated with one corporation and are now used as static demisters without use of or generation of water. The site using a boost charging scrubber utilizes recycle of coalescer-demister washdown water with caustic addition, incurring infrequent low volume blowdown to treatment. No information is available concerning the paint fume scrubber.

Two types of scrubbers were identified being used in lead battery manufacturing plants. These are; (1) a static vessel of scrubber water, or internally recirculated water, through which fumes are sparged and (2) an acid mist or fume coalescer with intermittent washdown. The static vessel design typifies leady oxide production, grid manufacture, battery assembly, and pasting applications; the latter design typifies formation area air scrubbing.

The static and internally recirculated designs are from two different manufacturers but both result in the same effective wastewater generation rates and blowdown requirements. The static design uses an induced draft system to pull the fumes to be controlled into a vessel of water. Submerged baffles direct the air stream through the water layer and subsequently to the atmosphere via a demister. No overflow is usually required and makeup is needed for water lost by evaporation and entrainment in the air stream. Some plants, however, steadily drain the tank while adding fresh makeup water.

The internal recirculation design reported recirculation of the scrubbing water through a set of baffles above the water layer to impinge particulates and absorb acid fumes. As with the static design, a demister removes most or all of the entrained water, requiring little makeup. Also, in current practice, these tanks are sometimes steadily drained and fresh water is added.

The primary function of these static and internal recirculation scrubber designs is to remove acid mists and to collect particulates. They are used on ball mills, lead melting pots, and paste mixers and collect lead particles which can be reclaimed. The predominate use of WAPC for paste mixing in the lead subcategory is as a precaution to avoid corrosion due to the possibility of acid in the paste mixing fumes.

Baghouses have been observed in use on ball mills, Barton process, paste mixers, and lead melt pots. When they can be used, they preclude the generation of wastewater. Baghouses are observed on paste mixing in order to recover and reuse lead dust. Acid in fumes from paste mixing and application does not appear, probably because of the neutralizing effect of lead oxides.

In summary, there are several ways to minimize water flow from static, batch WAPC scrubbers:

(1) Use of baghouses which is demonstrated in leady oxide production, pasting, and casting.

(2) Use an alkali to periodically adjust the pH in the tank to avoid equipment corrosion. This eliminates the need for continuous blowdown and allows batch dumping semi-annually.

(3) Use an external recycle system with a settling tank to collect bulk residuals which accumulate. This would still allow batch dumping of the stream water semi-annually.

One particular scrubber design is typically used in the formation area by lead subcategory plants. All major corporation plants which reported the use of a wet scrubber reported this type and no other type was reported at all.

In this type of scrubber, sulfuric acid fumes are scrubbed by two mechanisms. In the first mechanism, the centrifugal action of a fan removes about 60 percent of the sulfuric acid in the incoming air stream. In the second mechanism, the air passes through a mesh arrangement where the remaining acid fumes coalesce. The overall sulfuric acid removal efficiency is above 98 percent. The vendor of this system indicated that the scrubber should be operated dry with intermittent washdown of the mesh when scrubbing sulfuric acid fumes. The vendor also indicated that at some battery sites, a fine water spray is used in the fan section of the scrubber. The vendor indicated that this water spray is unnecessary when scrubbing sulfuric acid fumes. Sulfuric acid has a high molecular weight, consequently, the centrifugal action of the fan is sufficient to separate the sulfuric acid from the low molecular weight air stream. The water spray stream is unnecessary.

The sites reporting data vary in how mesh washdown water is handled, plus some sites report no washdown at all. This difference is believed to result entirely from the manner in which the mesh washdown is handled. Current washdown practice is largely represented by the use of once-through discharge designs. According to vendor-specified washdown techniques, a plant can recycle this water, with or without the use of an alkali, and maintain a minimum blowdown rate without resulting in equipment corrosion. The use of an alkali addition was reported to reduce the necessary blowdown rate by a factor of 100.

Based on observed and reported design and operating practices, the following alternative flow minimization techniques can be used with this type of scrubbing system:

(1) Do not use a water spray, as this practice is not necessary when scrubbing sulfuric acid fumes.

(2) Do not use a washdown, as some plants report only the use of the mesh to impinge and coalesce acid droplets resulting in negligible flow.

(3) Use external recirculation with no caustic addition, and use the blow down in acid cutting, plate rinsing or other processes.

(4) Use external recirculation with alkali addition to control pH and use the minimum required blowdown rate.

Virtually all plants use laboratories for quality control checks. Part of the laboratory equipment is a hood for ventilation during certain tests which generate lead dust or fumes. At two sites WAPC scrubbers were observed being used to control emissions from these hoods. These scrubbers are operated intermittently in conjunction with the hood operation. One plant operates a recirculating scrubber which incurs an intermittent overflow from the recirculation tank to treatment as a result of fresh water addition. The other plant operates the scrubber in a once-through mode. Flow minimization for laboratory scrubbers comprises operation of the scrubber (i.e., water flow) only when the hood is operated.

Truck Wash - Trailers are used for hauling finished batteries to distribution, batteries to repair facilities and for other non-secondary lead related activities. These trailers are sometimes washed down on-site. A mechanism for reducing overall water use is to conduct the washdown procedure in two phases: the first phase would use treated wastewater to remove contamination, and the second phase would use fresh water to avoid any dissolved salt buildup.

Lead Subcategory Other In-Process Control Techniques

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.

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 addition, effective plant maintenance and housekeeping practices may reduce or eliminate some process wastewater sources. Plant maintenance practices, such as (1) epoxy coating of racks and equipment which contact process wastewater and (2) 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 plants, 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 cleanup techniques.

Control of lead dust within the plant also represents a significant water use at some plants 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 cleanup techniques can reduce or eliminate the volume of discharge from this source. Examples of water efficient cleanup techniques include floor wash machines and bucket and mop floor washing.

Equipment maintenance may also contribute significantly to wastewater discharge reduction. At one plant, 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 because of the corrosive nature 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.

TABLE VII-1
pH CONTROL EFFECT ON METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range	2.4-3.4	8.5-8.7	1.0-3.0	5.0-6.0	2.0-5.0	6.5-8.1
(mg/l)						
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

TABLE VII-2

EFFECTIVENESS OF SODIUM HYDROXIDE FOR METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	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

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
Co	3.92	0.0	4.65	0.0	4.37	0.0
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

TABLE VII-4

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF SELECTED METALS IN PURE WATER

	Solubility of metal ion, mg/l		
Metal	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	0.01	0.060	0.009

These data were obtained from three sources:

Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, USEPA, EPA No. 625/8/80-003, 1979.

Industrial Finishing, Vol. 35, No. 11, November, 1979.

Electroplating sampling data from plant 27045.

TABLE VII-6

SULFIDE PRECIPITATION-SEDIMENTATION PERFORMANCE

Parameter	Treated Effluent (mg/l)
Cd	0.01
Cr (T)	0.05
Cu	0.05
Pb	0.01
Hg	0.03
Ni	0.05
Ag	0.05
Zn	0.01

Table VII-6 is based on two reports:

Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, USEPA, EPA No. 625/8/80-003, 1979.

Addendum to Development Document for Effluent Limitations Guidelines and New Source Performance Standards, Major Inorganic Products Segment of Inorganics Point Source Category, USEPA., EPA Contract No. EPA-68-01-3281 (Task 7), June, 1978.

Table VII-7

FERRITE CO-PRECIPITATION PERFORMANCE

Metal	Influent(mg/l)	Effluent(mg/l)
Mercury	7.4	0.001
Cadmium	240	0.008
Copper	10	0.010
Zinc	18	0.016
Chromium	10	<0.010
Manganese	12	0.007
Nickel	1,000	0.200
Iron	600	0.06
Bismuth	240	0.100
Lead	475	0.010

NOTE: These data are from:
Sources and Treatment of Wastewater in the Nonferrous Metals Industry, USEPA, EPA No. 600/2-80-074, 1980.

TABLE VII-8

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

Table VII-9

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

TABLE VII-10
PERFORMANCE OF SELECTED 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

Table VII-11

SKIMMING PERFORMANCE

		Oil & Grease mg/l	
Plant	Skimmer Type	In	Out
06058	API	224,669	17.9
06058	Belt	19.4	8.3

TABLE VII-12

SELECTED PARITION COEFFICIENTS

Priority Pollutant		Log Octanol/Water Partition Coefficient
1	Acenaphthene	4.33
11	1,1,1-Trichloroethane	2.17
13	1,1-Dichloroethane	1.79
15	1,1,2,2-Tetrachloroethane	2.56
18	Bis(2-chloroethyl)ether	1.58
23	Chloroform	1.97
29	1,1-Dichloroethylene	1.48
39	Fluoranthene	5.33
44	Methylene chloride	1.25
64	Pentachlorophenol	5.01
66	Bis(2-ethylhexyl) phthalate	8.73
67	Butyl benzyl phthalate	5.80
68	Di-n-butyl phthalate	5.20
72	Benzo(a)anthracene	5.61
73	Benzo(a)pyrene	6.04
74	3,4-benzofluoranthene	6.57
75	Benzo(k)fluoranthene	6.84
76	Chrysene	5.61
77	Acenaphthylene	4.07
78	Anthracene	4.45
79	Benzo(ghi)perylene	7.23
80	Fluorene	4.18
81	Phenanthrene	4.46
82	Dibenzo(a,h)anthracene	5.97
83	Indeno(1,2,3,cd)pyrene	7.66
84	Pyrene	5.32
85	Tetrachloroethylene	2.88
86	Toluene	2.69

TABLE VII-13

TRACE ORGANIC REMOVAL BY SKIMMING
API PLUS BELT SKIMMERS
(From Plant 06058)

	Inf. mg/l	Eff. mg/l
Oil & Grease	225,000	14.6
Chloroform	0.023	0.007
Methylene Chloride	0.013	0.012
Naphthalene	2.31	0.004
N-nitrosodiphenylamine	59.0	0.182
Bis-2-ethylhexyl phthalate	11.0	0.027
Diethyl phthalate	-	-
Butylbenzyl phthalate	0.005	0.002
Di-n-octyl phthalate	0.019	0.002
Anthracene - phenanthrene	16.4	0.014
Toluene	0.02	0.012

Table VII-14

COMBINED METALS DATA EFFLUENT VALUES (mg/l)

	Mean	One Day Max.	10 Day Avg. Max.	30 Day Avg. Max.
Cd	0.079	0.34	0.15	0.13
Cr	0.084	0.44	0.18	0.12
Cu	0.58	1.90	1.00	0.73
Pb	0.12	0.42	0.20	0.16
Ni	0.74	1.92	1.27	1.00
Zn	0.33	1.46	0.61	0.45
Fe	0.41	1.20	0.61	0.50
Mn	0.16	0.68	0.29	0.21
TSS	12.0	41.0	19.5	15.5

TABLE VII-15
L&S PERFORMANCE
ADDITIONAL POLLUTANTS

Pollutant	Average Performance (mg/l)
Sb	0.7
As	0.51
Be	0.30
Hg	0.06
Se	0.30
Ag	0.10
Tl	0.50
Al	2.24
Co	0.05
F	14.5

TABLE VII-16

COMBINED METALS DATA SET - UNTREATED WASTEWATER

Pollutant	Min. Conc (mg/l)	Max. Conc. (mg/l)
Cd	<0.1	3.83
Cr	<0.1	116
Cu	<0.1	108
Pb	<0.1	29.2
Ni	<0.1	27.5
Zn	<0.1	337.
Fe	<0.1	263
Mn	<0.1	5.98
TSS	4.6	4390

TABLE VII-17
MAXIMUM POLLUTANT LEVEL IN UNTREATED WASTEWATER

ADDITIONAL POLLUTANTS
(mg/l)

Pollutant	As & Se	Be	Ag	F	Sb
Sb	-	-	-	-	8.5
As	4.2	-	-	-	0.024
Be	-	10.24	-	-	-
Cd	<0.1	-	<0.1	<0.1	0.83
Cr	0.18	8.60	0.23	22.8	-
Cu	33.2	1.24	110.5	2.2	0.41
Pb	6.5	0.35	11.4	5.35	76.0
Ni	-	-	100	0.69	-
Ag	-	-	4.7	-	-
Zn	3.62	0.12	1512	<0.1	0.53
F	-	-	-	760	-
Fe	-	646	-	-	-
O&G	16.9	-	16	2.8	-
TSS	352	796	587.8	5.6	134

TABLE VII-18

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-19

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 -466.		

TABLE VII-20

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant C

For Treated Wastewater Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For Treated Wastewater				
Cd	103	0.010 - 0.500	0.049 ±0.049	0.147
Zn	103	0.039 - 0.899	0.290 ±0.131	0.552
TSS	103	0.100 - 5.00	1.244 ±1.043	3.33
pH	103	7.1 - 7.9	9.2*	
For Untreated Wastewater				
Cd	103	0.039 - 2.319	0.542 ±0.381	1.304
Zn	103	0.949 -29.8	11.009 ±6.933	24.956
Fe	3	0.107 - 0.46	0.255	
TSS	103	0.80 -19.6	5.616 ±2.896	11.408
pH	103	6.8 - 8.2	7.6*	

* pH value is median of 103 values.

TABLE VII-21

SUMMARY OF TREATMENT EFFECTIVENESS (mg/l)

Pollutant Parameter		L & S Technology System				LS&F Technology System				Sulfide Precipitation Filtration			
		Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.	Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.	Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.
114	Sb	0.70	2.87	1.28	1.14	0.47	1.93	0.86	0.76				
115	As	0.51	2.09	0.86	0.83	0.34	1.39	0.57	0.55				
117	Be	0.30	1.23	0.51	0.49	0.20	0.82	0.34	0.32				
118	Cd	0.079	0.34	0.15	0.13	0.049	0.20	0.08	0.08	0.01	0.04	0.018	0.016
119	Cr	0.084	0.44	0.18	0.12	0.07	0.37	0.15	0.10	0.08	0.21	0.091	0.081
120	Cu	0.58	1.90	1.00	0.73	0.39	1.28	0.61	0.49	0.05	0.21	0.091	0.081
121	CN	0.07	0.29	0.12	0.11	0.047	0.20	0.08	0.08				
122	Pb	0.12	0.42	0.20	0.16	0.08	0.28	0.13	0.11	0.01	0.04	0.018	0.016
123	Hg	0.06	0.25	0.10	0.10	0.036	0.15	0.06	0.06	0.03	0.13	0.0555	0.049
124	Ni	0.74	1.92	1.27	1.00	0.22	0.55	0.37	0.29	0.05	0.21	0.091	0.081
125	Se	0.30	1.23	0.55	0.49	0.20	0.82	0.37	0.33				
126	Ag	0.10	0.41	0.17	0.16	0.07	0.29	0.12	0.10	0.05	0.21	0.091	0.081
127	Tl	0.50	2.05	0.84	0.81	0.34	1.40	0.57	0.55				
128	Zn	0.33	1.46	0.61	0.45	0.23	1.02	0.42	0.31	0.01	0.04	0.018	0.016
	Al	2.24	6.43	3.20	2.52	1.49	6.11	2.71	2.41				
	Co	0.05	0.21	0.09	0.08	0.034	0.14	0.07	0.06				
	F	14.5	59.5	26.4	23.5		59.5	26.4	23.5				
	Fe	0.41	1.20	0.61	0.50	0.28	1.20	0.61	0.50				
	Mn	0.16	0.68	0.29	0.21	0.14	0.30	0.23	0.19				
	P	4.08	16.7	6.83	6.60	2.72	11.2	4.6	4.4				
	O&G		20.0	12.0	10.0		10.0	10.0	10.0				
	TSS	12.0	41.0	19.5	15.5	2.6	15.0	12.0	10.0				

TABLE VII-22
TREATABILITY RATING OF PRIORITY POLLUTANTS UTILIZING CARBON ADSORPTION

Priority Pollutant	*Removal Rating
1. acenaphthene	H
2. acrolein	L
3. acrylonitrile	L
4. benzene	M
5. benzidine	H
6. carbon tetrachloride (tetrachloromethane)	M
7. chlorobenzene	H
8. 1,2,3-trichlorobenzene	H
9. hexachlorobenzene	H
10. 1,2-dichloroethane	M
11. 1,1,1-trichloroethane	M
12. hexachloroethane	H
13. 1,1-dichloroethane	M
14. 1,1,2-trichloroethane	M
15. 1,1,2,2-tetrachlorethane	H
16. chloroethane	L
17. bis(chloromethyl) ether	-
18. bis(2-chloroethyl) ether	M
19. 2-chloroethylvinyl ether (mixed)	L
20. 2-chloronaphthalene	H
21. 2,4,6-trichlorophenol	H
22. parachlorometa cresol	H
23. chloroform (trichloromethane)	L
24. 2-chlorophenol	H
25. 1,2-dichlorobenzene	H
26. 1,3-dichlorobenzene	H
27. 1,4-dichlorobenzene	H
28. 3,3'-dichlorobenzidine	H
29. 1,1-dichloroethylene	L
30. 1,2-trans-dichloroethylene	L
31. 2,4-dichlorophenol	H
32. 1,2-dichloropropane	M
33. 1,2-dichloropropylene (1,3-dichloropropene)	M
34. 2,4-dimethylphenol	H
35. 2,4-dinitrotoluene	H
36. 2,6-dinitrotoluene	H
37. 1,2-diphenylhydrazine	H
38. ethylbenzene	M
39. fluoranthene	H
40. 4-chlorophenyl phenyl ether	H
41. 4-bromophenyl phenyl ether	H
42. bis(2-chloroisopropyl)ether	M
43. bis(2-chloroethoxy)methane	M
44. methylene chloride (dichloromethane)	L
45. methyl chloride (chloromethane)	L
46. methyl bromide (bromomethane)	L
47. bromoform (tribromomethane)	H
48. dichlorobromomethane	M
49. trichlorofluoromethane	M
50. dichlorodifluoromethane	L
51. chlorodibromomethane	M
52. hexachlorobutadiene	H
53. hexachlorocyclopentadiene	H
54. isophorone	H
55. naphthalene	H
56. nitrobenzene	H
57. 2-nitrophenol	H
58. 4-nitrophenol	H
59. 2,4-dinitrophenol	H
60. 4,6-dinitro-o-cresol	H
61. N-nitrosodimethylamine	M
62. N-nitrosodiphenylamine	H
63. N-nitrosodi-n-propylamine	M
64. pentachlorophenol	H
65. phenol	M
66. bis(2-ethylhexyl)phthalate	H
67. butyl benzyl phthalate	H
68. di-n-butyl phthalate	H
69. di-n-octyl phthalate	H
70. diethyl phthalate	H
71. dimethyl phthalate	H
72. 1,2-benzanthracene (benzo(a)anthracene)	H
73. benzo(a)pyrene (3,4-benzopyrene)	H
74. 3,4-benzofluoranthene (benzo(b)fluoranthene)	H
75. 11,12-benzofluoranthene (benzo(k)fluoranthene)	H
76. chrysene	H
77. acenaphthylene	H
78. anthracene	H
79. 1,12-benzoperylene (benzo (ghi)-perylene)	H
80. fluorene	H
81. phenanthrene	H
82. 1,2,3,6-dibenzanthracene (dibenzo(a,h) anthracene)	H
83. indeno (1,2,3-cd) pyrene (2,3-o-phenylene pyrene)	H
84. pyrene	-
85. tetrachloroethylene	M
86. toluene	M
87. trichloroethylene	L
88. vinyl chloride (chloroethylene)	L
106. PCB-1242 (Aroclor 1242)	H
107. PCB-1254 (Aroclor 1254)	H
108. PCB-1221 (Aroclor 1221)	H
109. PCB-1332 (Aroclor 1232)	H
110. PCB-1248 (Aroclor 1248)	H
111. PCB-1260 (Aroclor 1260)	H
112. PCB-1016 (Aroclor 1016)	H

*Note Explanation of Removal Ratings

Category H (high removal)

adsorbs at levels ≥ 100 mg/g carbon at $C_f = 10$ mg/l

adsorbs at levels ≥ 100 mg/g carbon at $C_f < 1.0$ mg/l

Category M (moderate removal)

adsorbs at levels ≥ 100 mg/g carbon at $C_f = 10$ mg/l

adsorbs at levels ≤ 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 - 23

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, pentachlorophenol
*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 and Alcohols	hydroquinone, polyethylene glycol
Surfactants	alkyl benzene sulfonates
Soluble Organic Dyes	methylene blue, indigo carmine

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* High Molecular Weight includes compounds in the broad range of from 4 to 20 carbon atoms

Table VII-24

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

Table VII-25

ION EXCHANGE PERFORMANCE

Parameter	Plant A		Plant B	
All Values mg/l	Prior To Purification	After Purification	Prior To Purification	After Purification
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	-	-

Table VII-26

MEMBRANE FILTRATION SYSTEM EFFLUENT

Specific Metal	Manufacturers Guarantee	Plant 19066 In	Plant 19066 Out	Plant 31022 In	Plant 31022 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	1.0

Table VII-27

PEAT ADSORPTION 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

Table VII-28

ULTRAFILTRATION PERFORMANCE

Parameter	Feed (mg/l)	Permeate (mg/l)
Oil (freon extractable)	1230	4
COD	8920	148
TSS	1380	13
Total Solids	2900	296

TABLE VII-29

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

	WASTEWATER RECYCLE AND REUSE 1/						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														
	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-29 (Continued)

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

	WASTEWATER RECYCLE AND REUSE 1/							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 (Continued)														
								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-29 (Continued)

PROCESS CONTROL TECHNOLOGIES IN USE AT BATTERY MANUFACTURE PLANTS

	WASTEWATER RECYCLE AND REUSE 1/							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 (Continued)														
	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

1/ Recycle or reuse following treatment indicated by *.

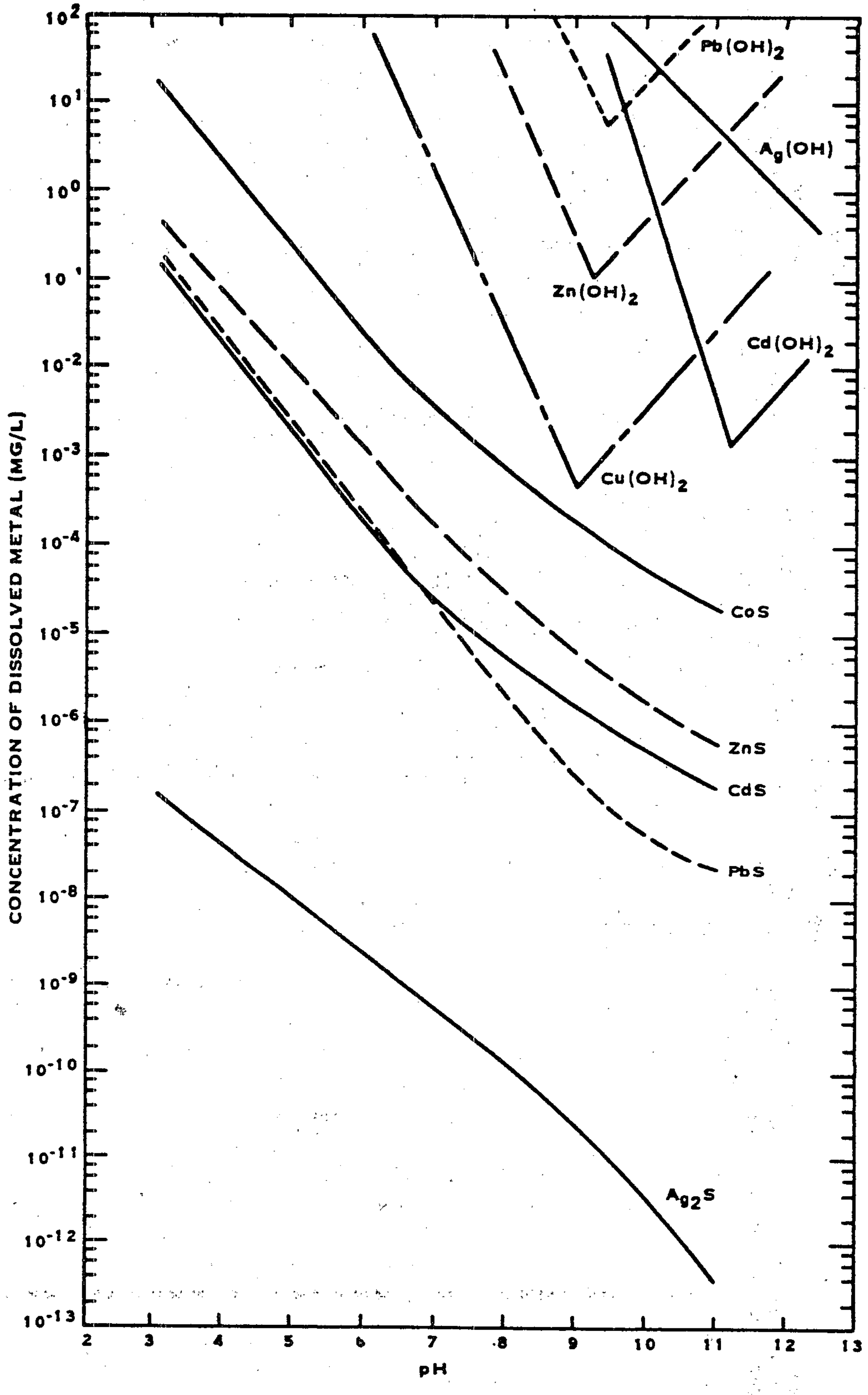


FIGURE VII - 1. COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES AND SULFIDE AS A FUNCTION OF pH

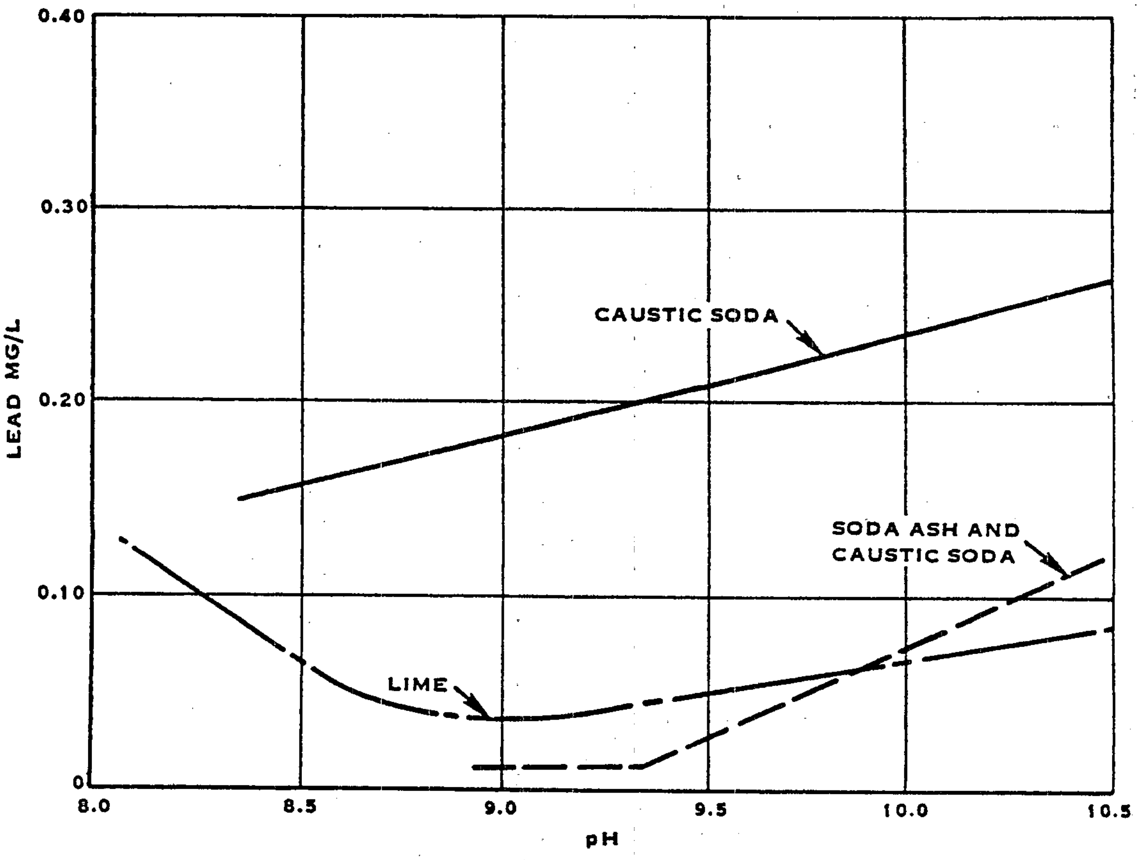


FIGURE VII - 2. LEAD SOLUBILITY IN THREE ALKALIES

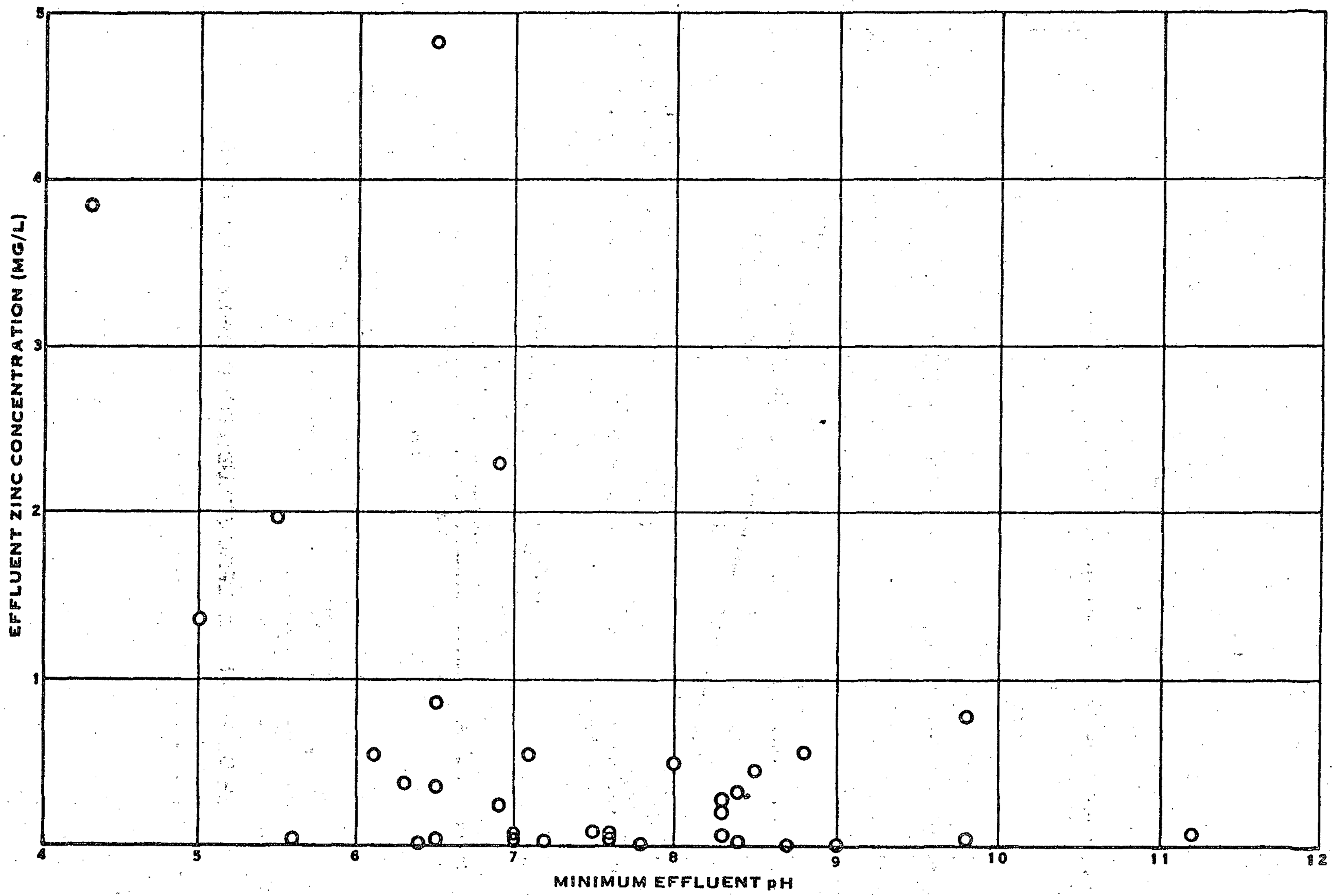
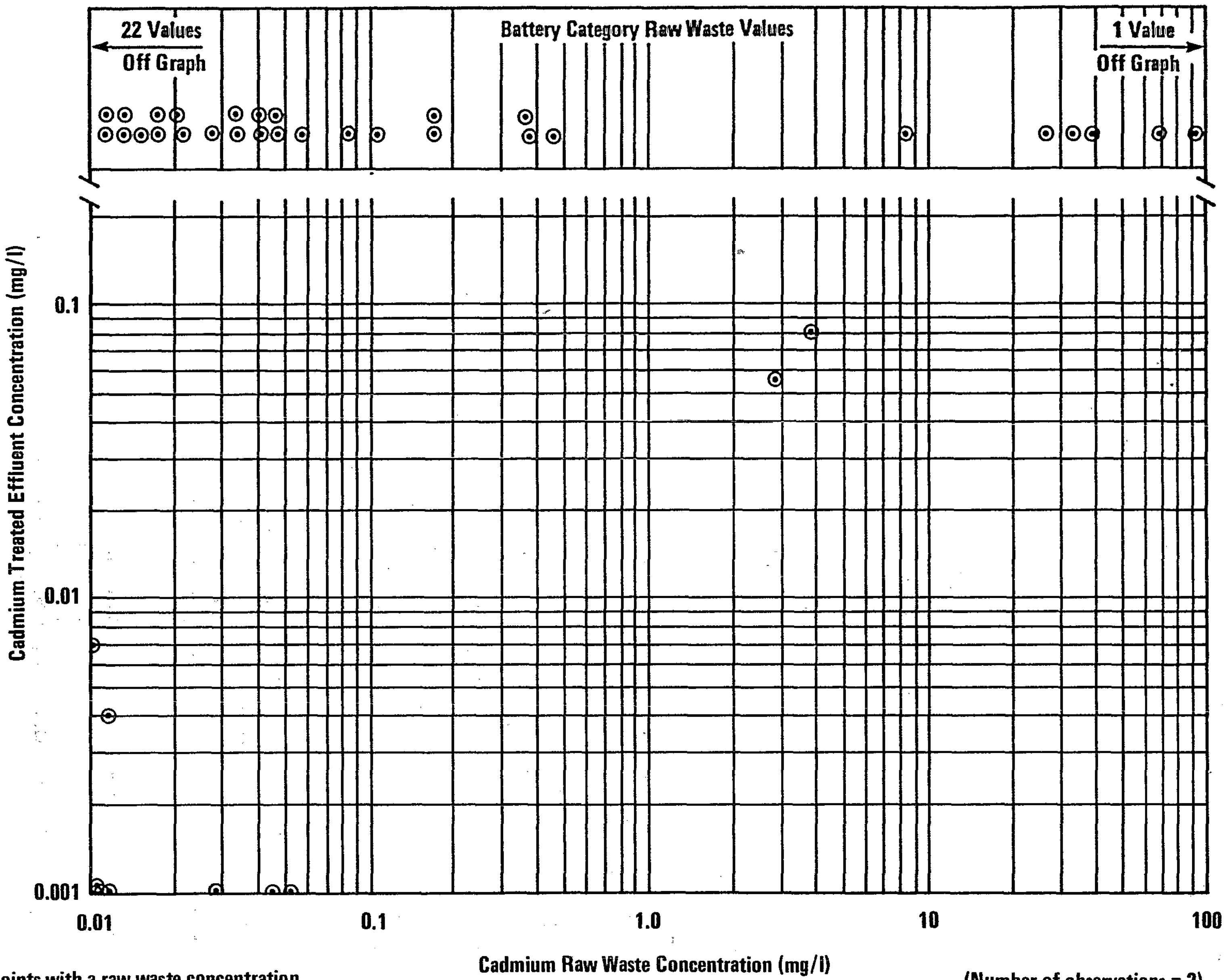


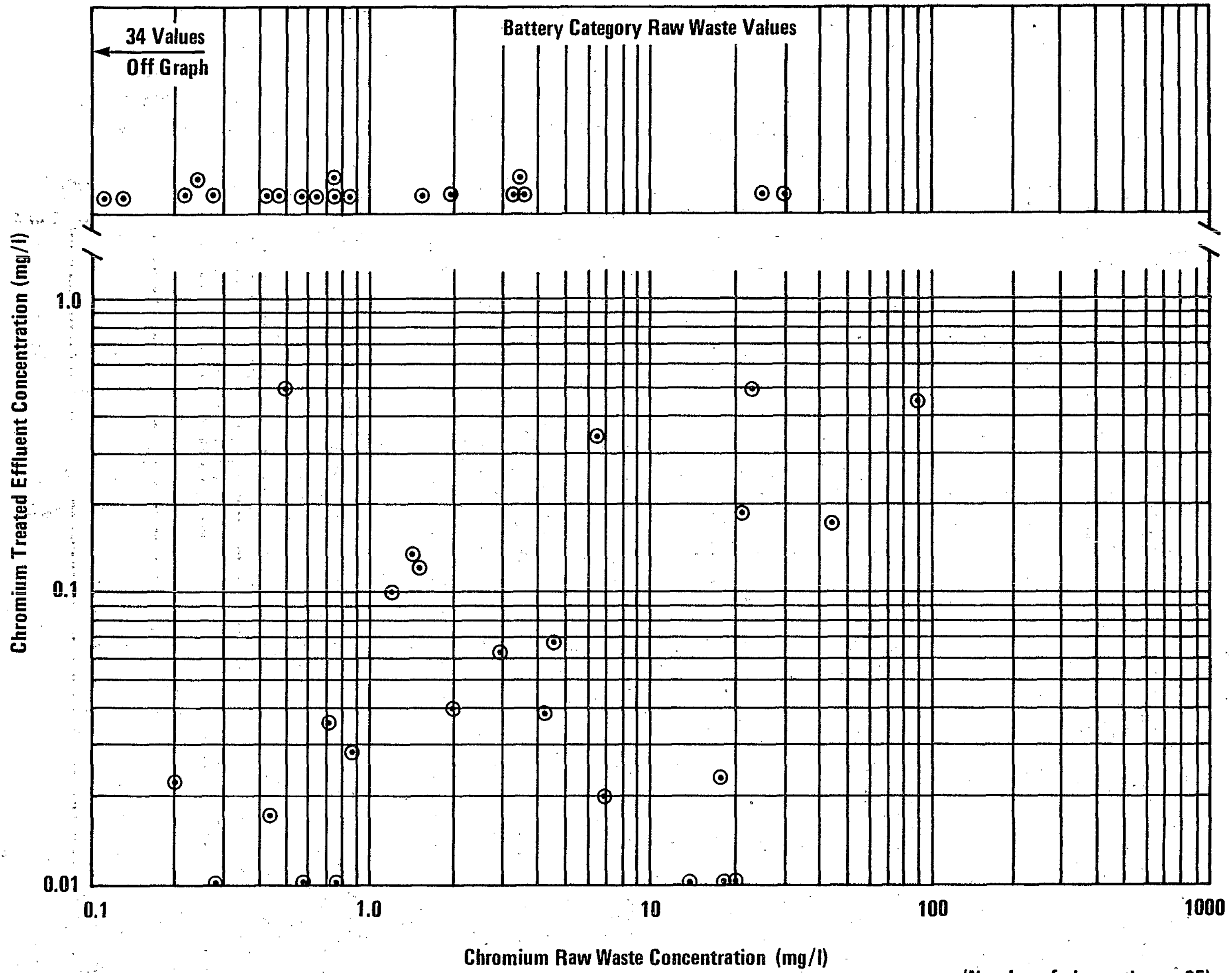
FIGURE VII-3. EFFLUENT ZINC CONCENTRATION VS. MINIMUM EFFLUENT pH



Data points with a raw waste concentration less than 0.1 mg/l were not included in treatment effectiveness calculations.

(Number of observations = 2)

FIGURE VII-4
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CADMIUM



(Number of observations = 25)

FIGURE VII-5
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CHROMIUM

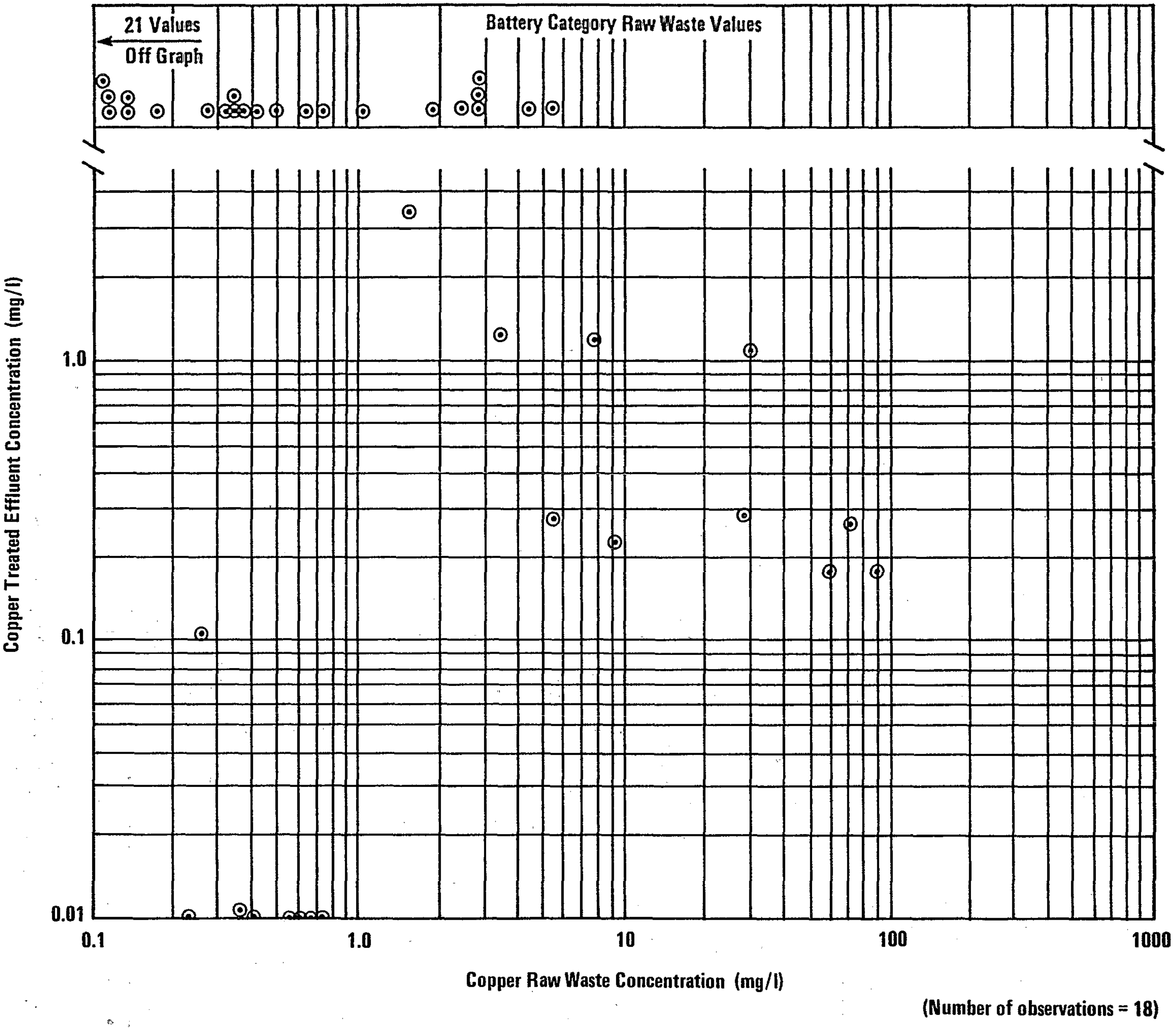


FIGURE VII-6
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
COPPER

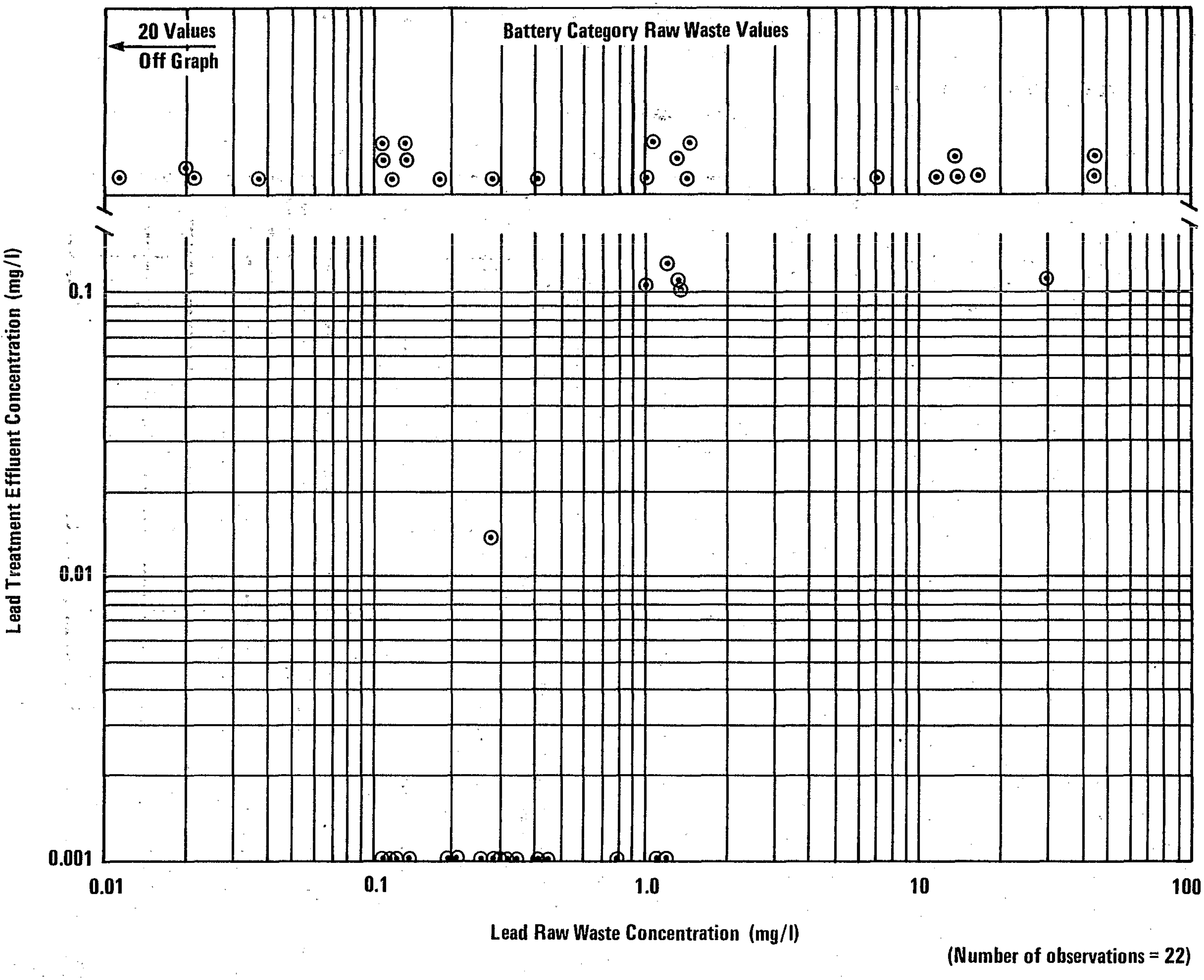


FIGURE VII-7
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
LEAD

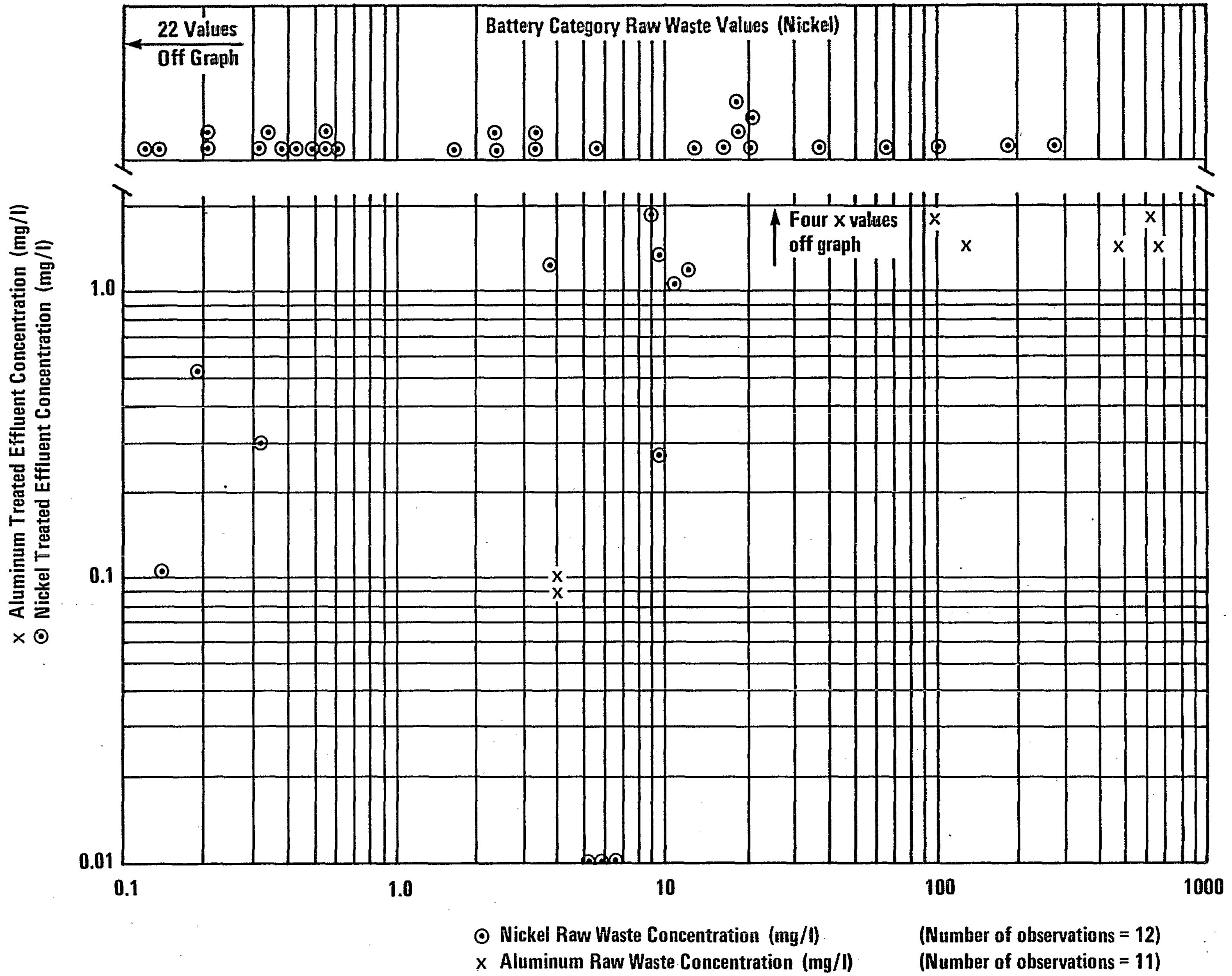
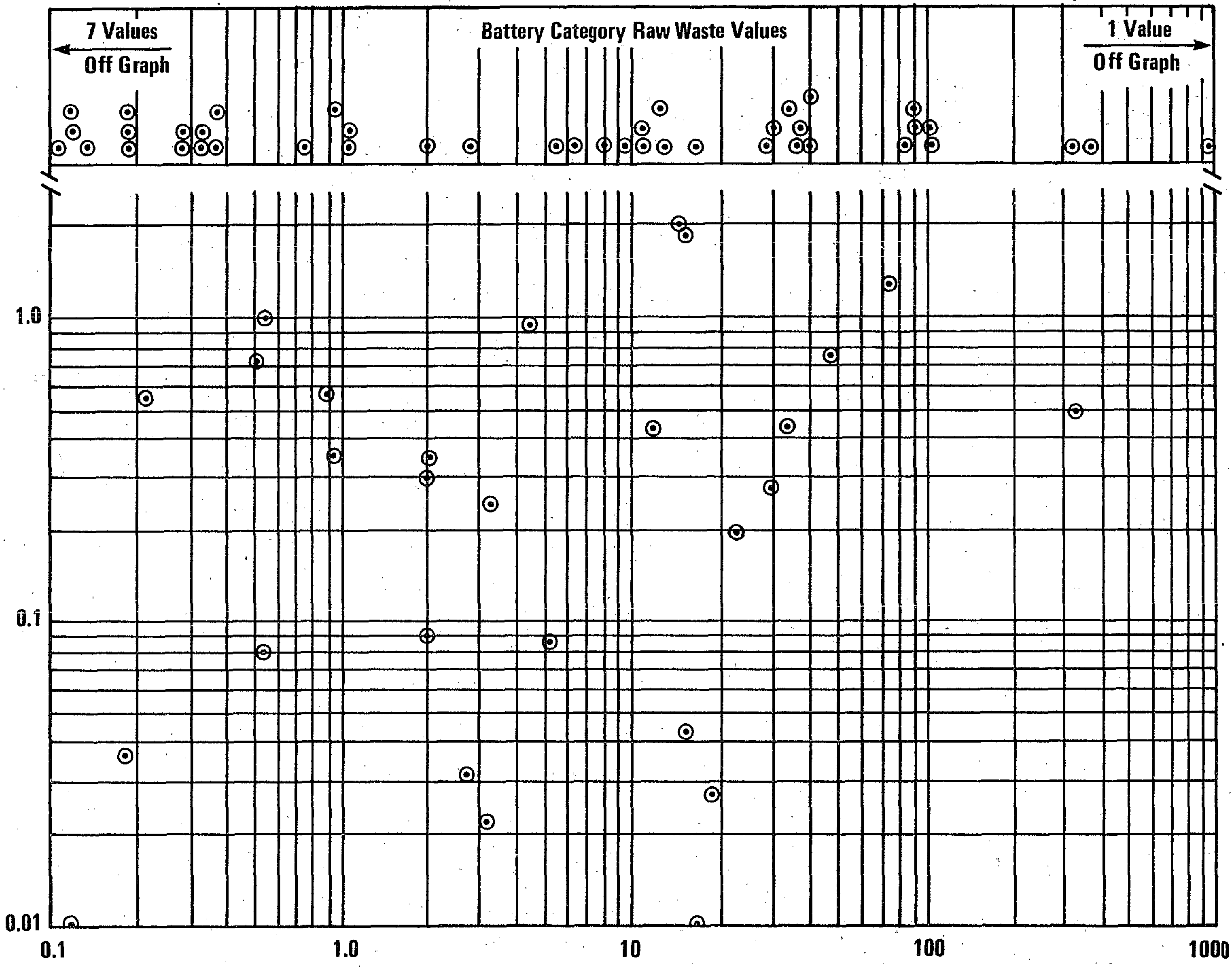
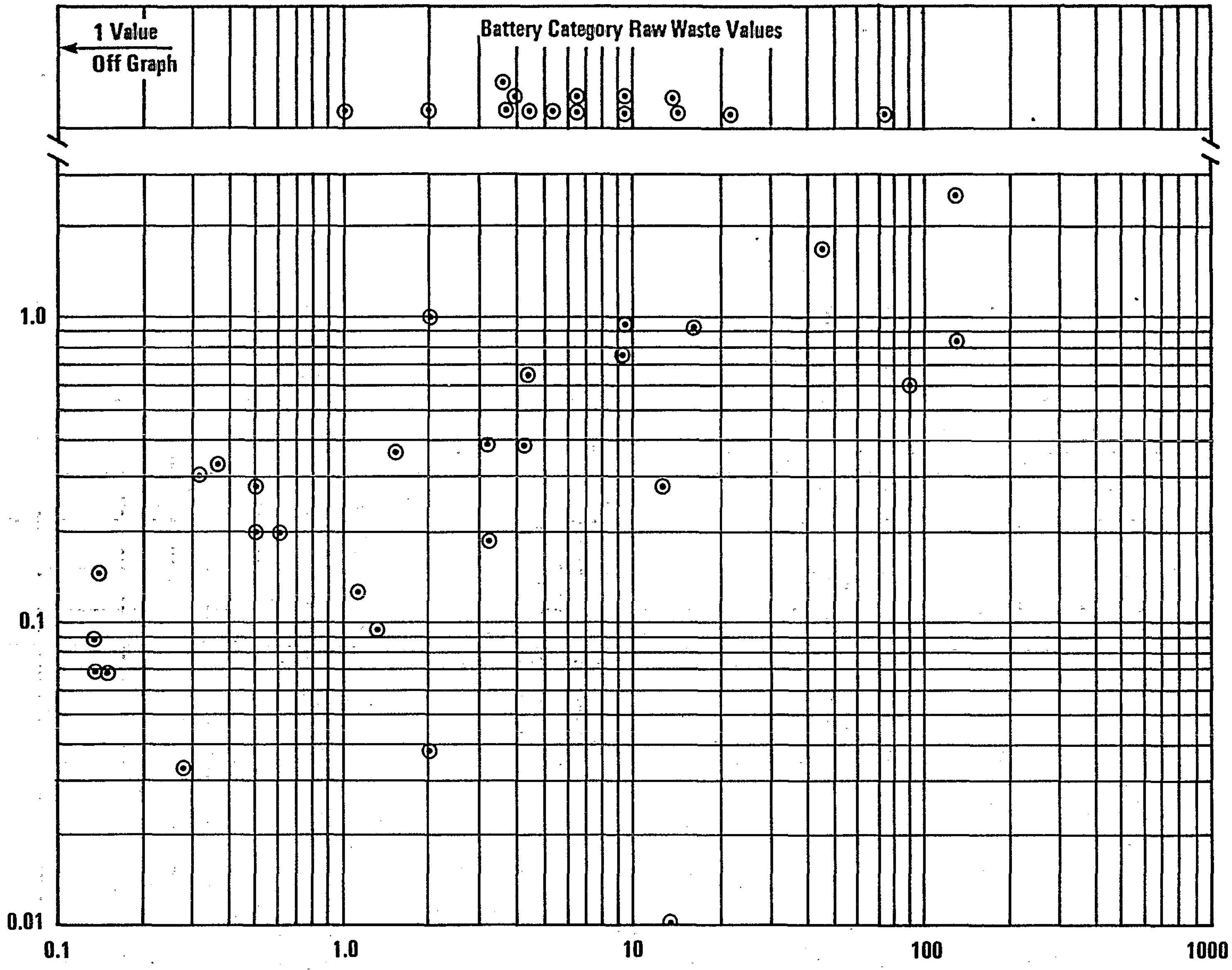


FIGURE VII-8
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
NICKEL AND ALUMINUM



(Number of observations = 28)

FIGURE VII-9
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
ZINC



(Number of observations = 28)

FIGURE VII-10
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
IRON

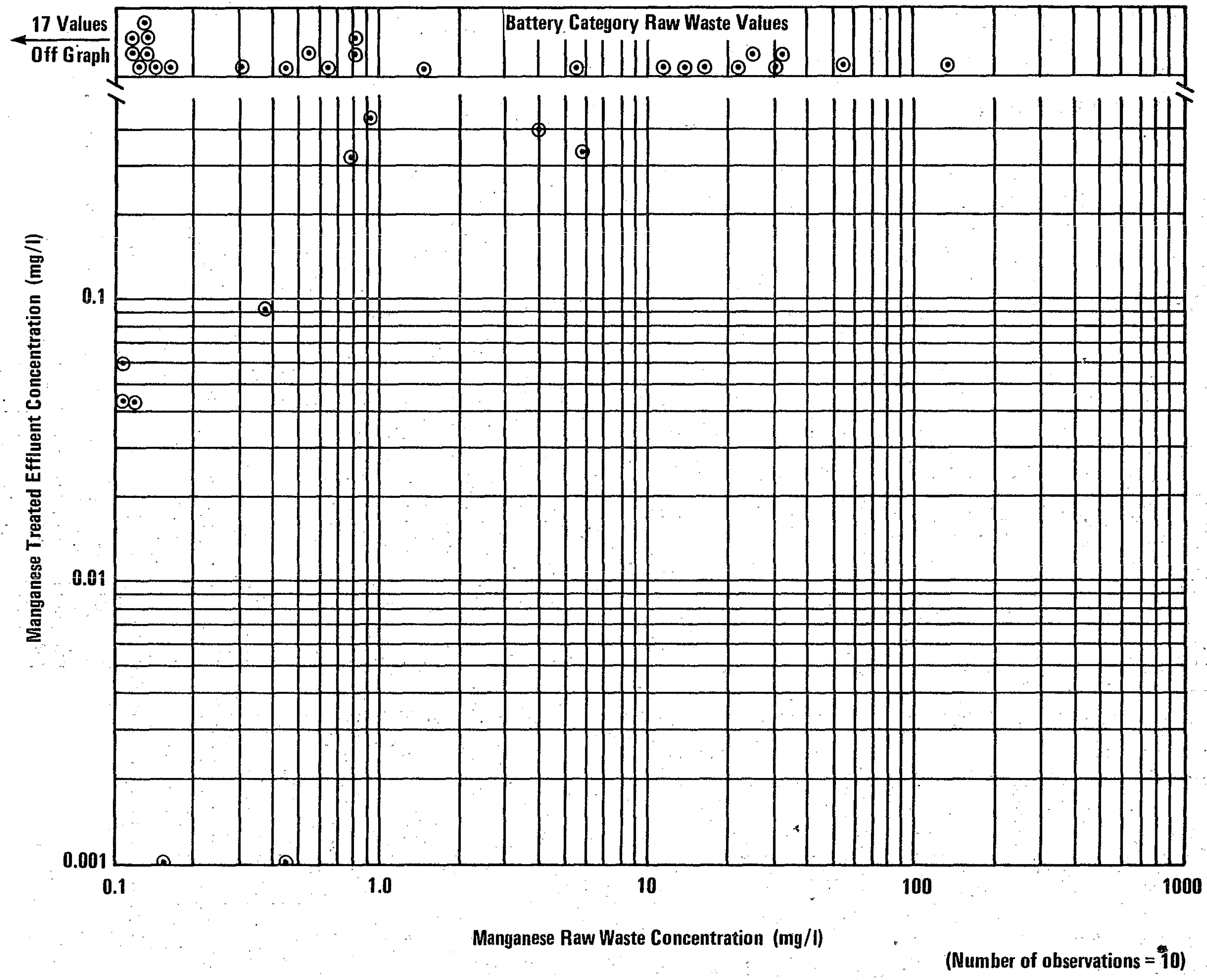
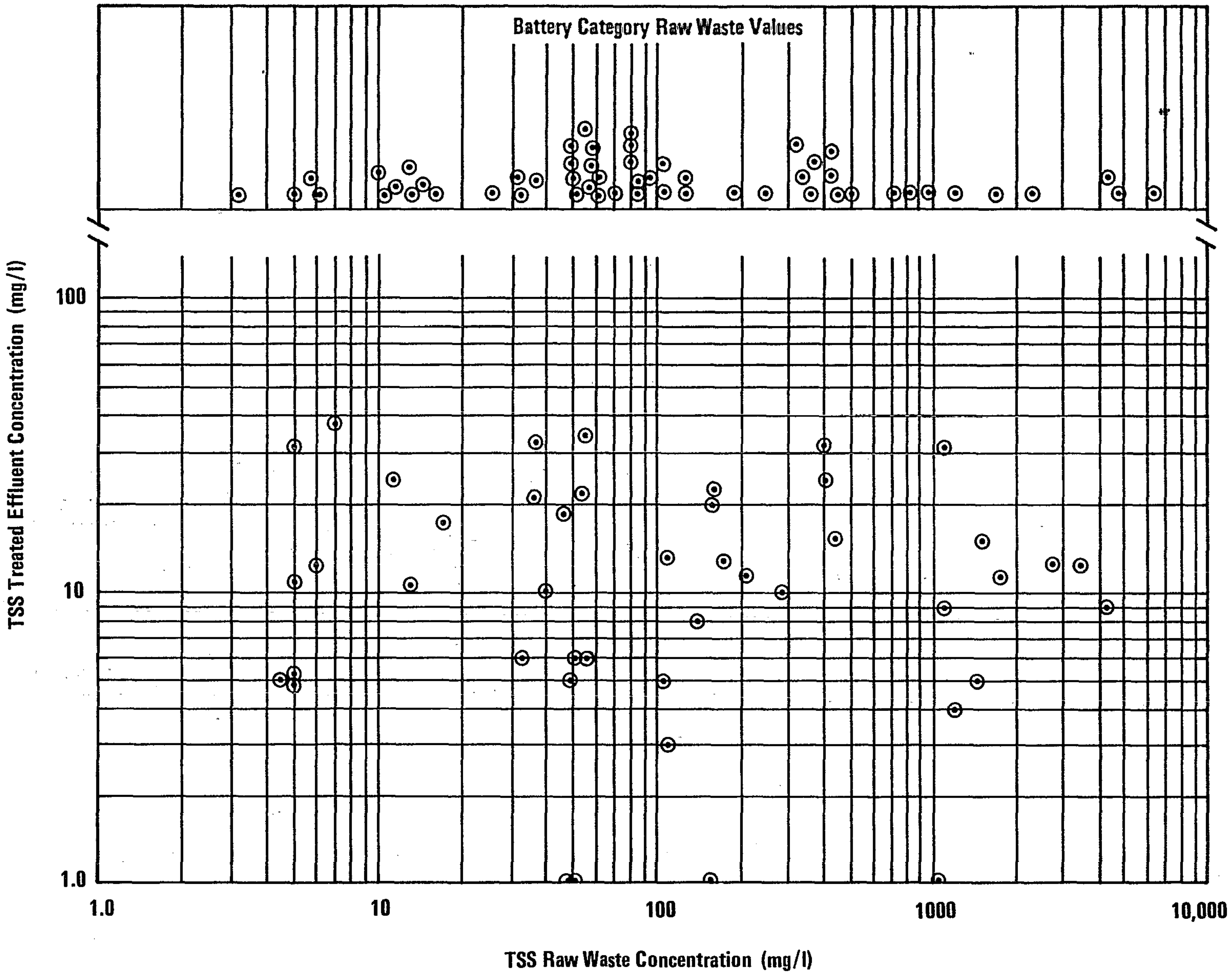


FIGURE VII-11
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
MANGANESE



(Number of observation = 45)

FIGURE VII-12
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
TSS

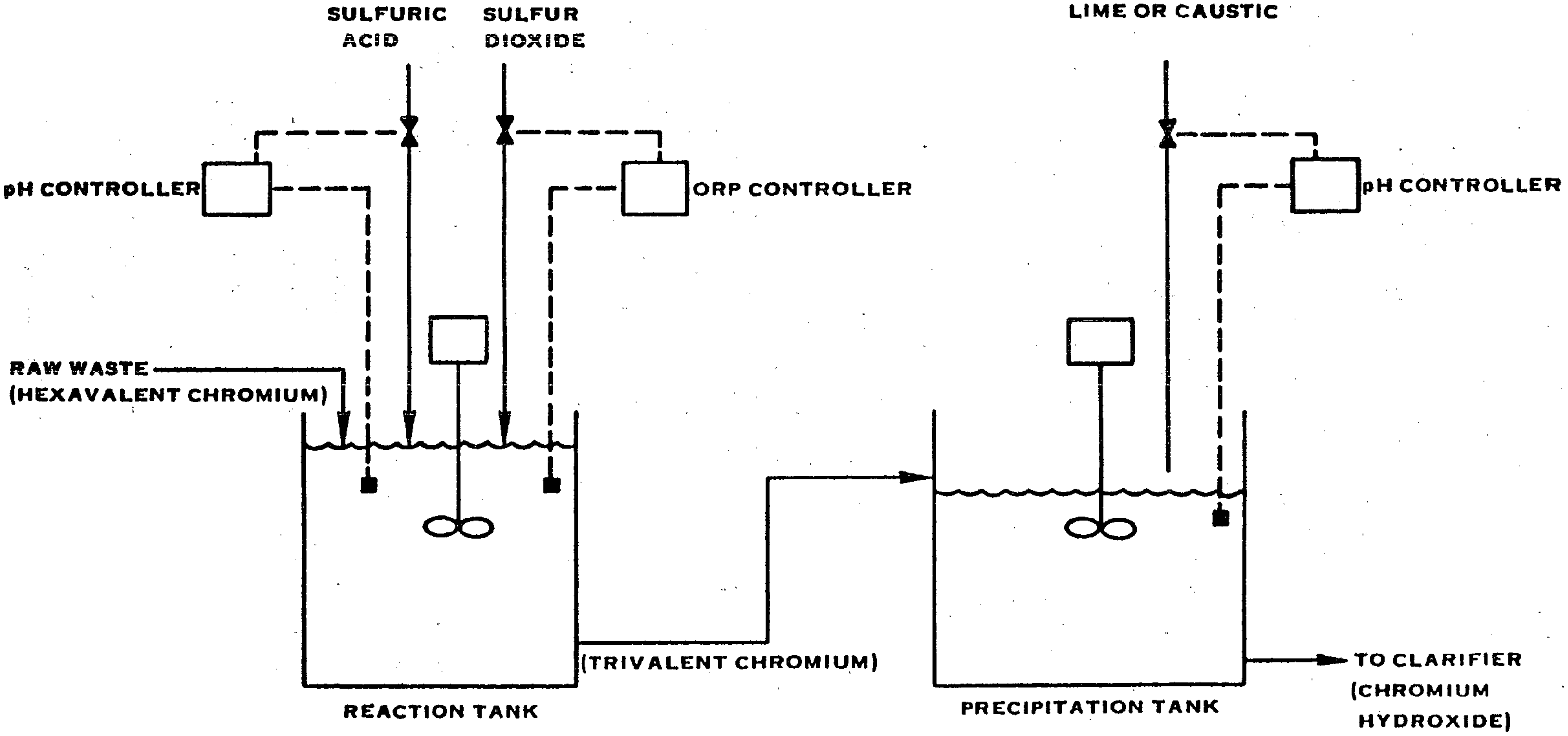


FIGURE VII-13. HEXAVALENT CHROMIUM REDUCTION WITH SULFUR DIOXIDE

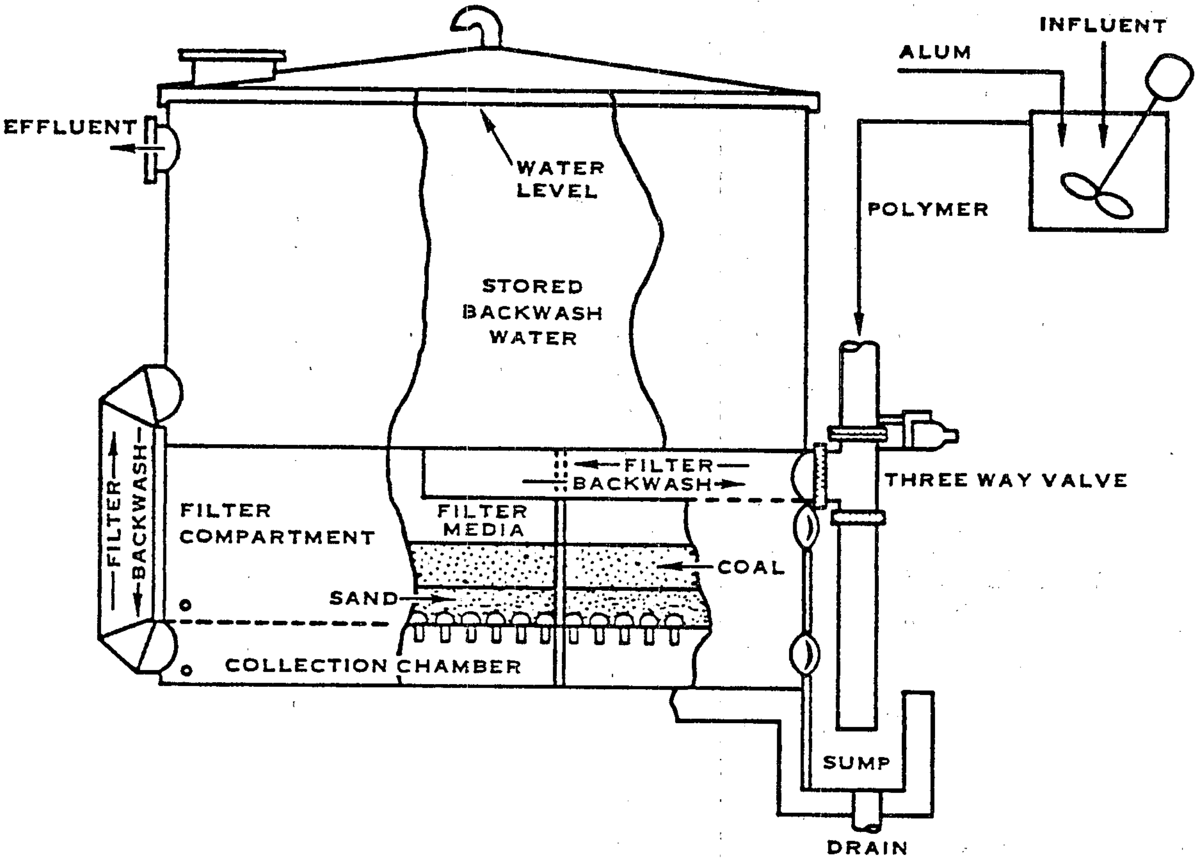


FIGURE VII-14. GRANULAR BED FILTRATION

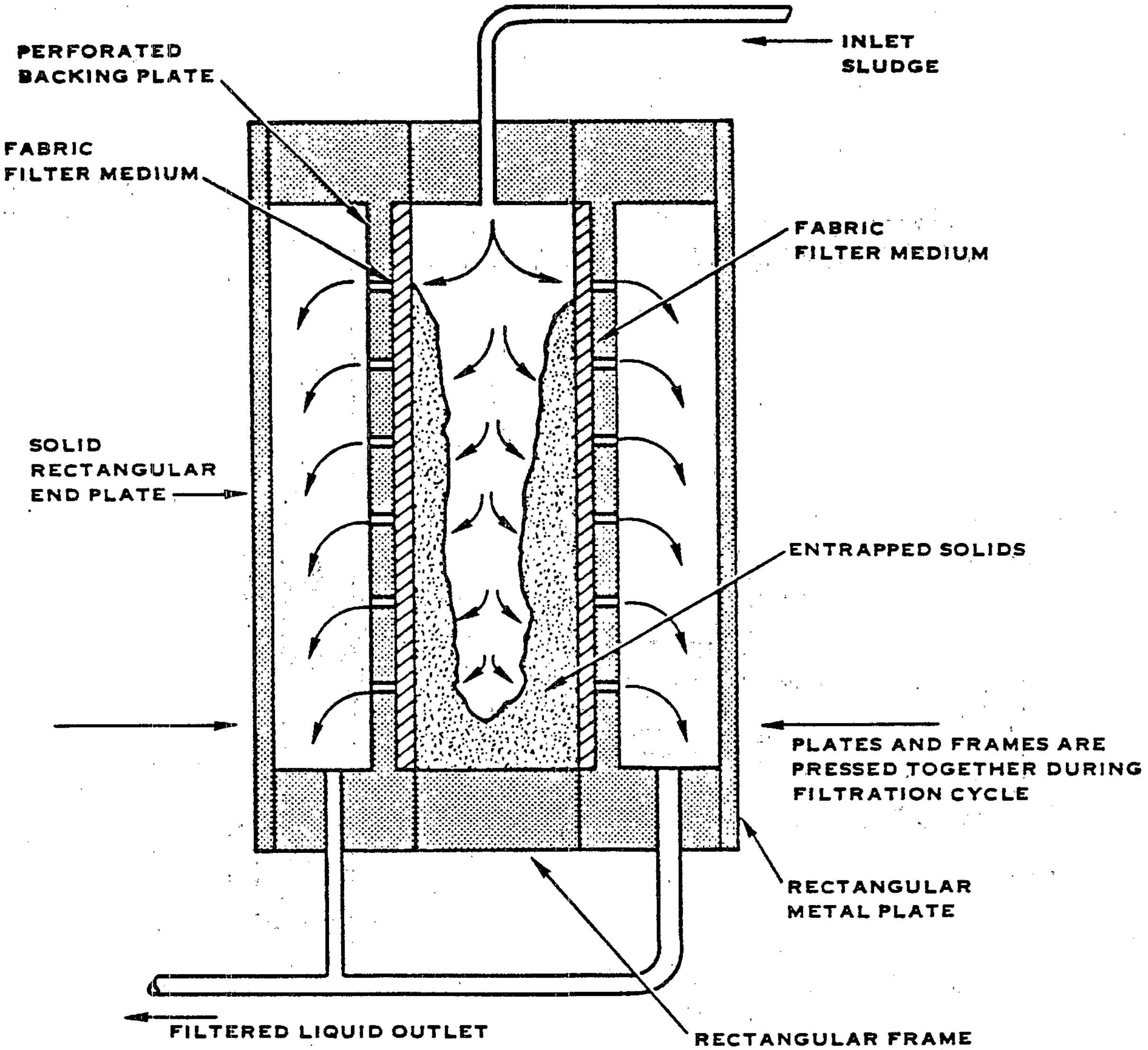
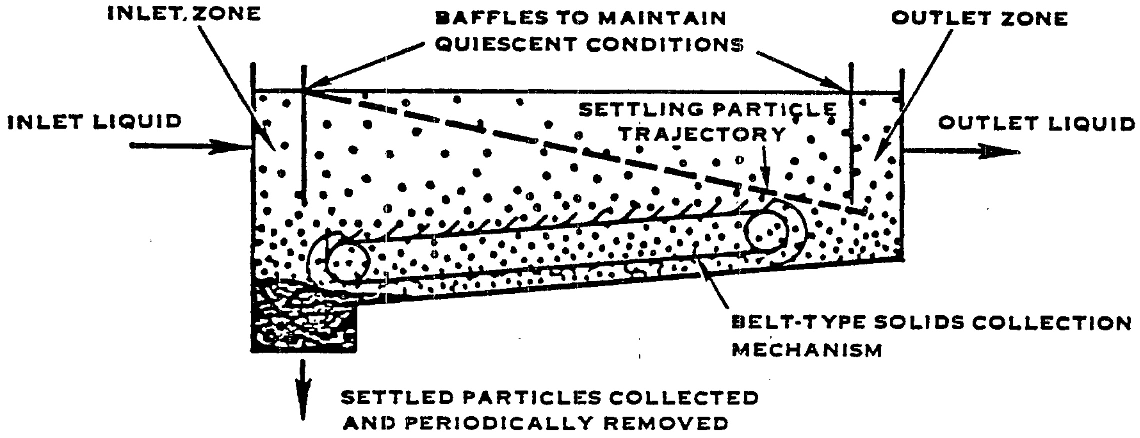


FIGURE VII-15. PRESSURE FILTRATION

SEDIMENTATION BASIN



CIRCULAR CLARIFIER

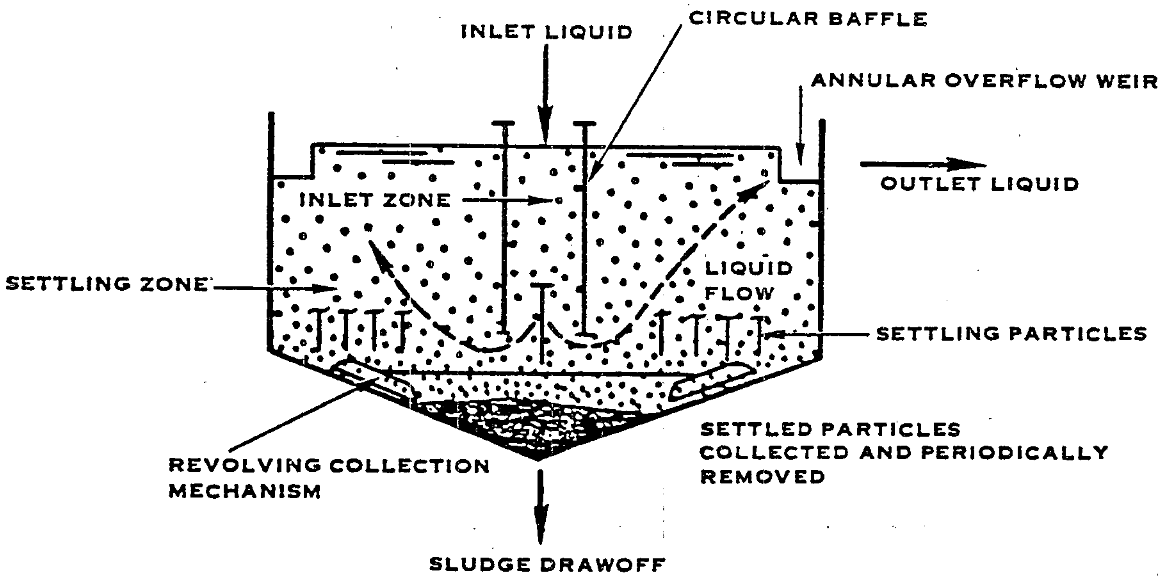


FIGURE VII-16. REPRESENTATIVE TYPES OF SEDIMENTATION

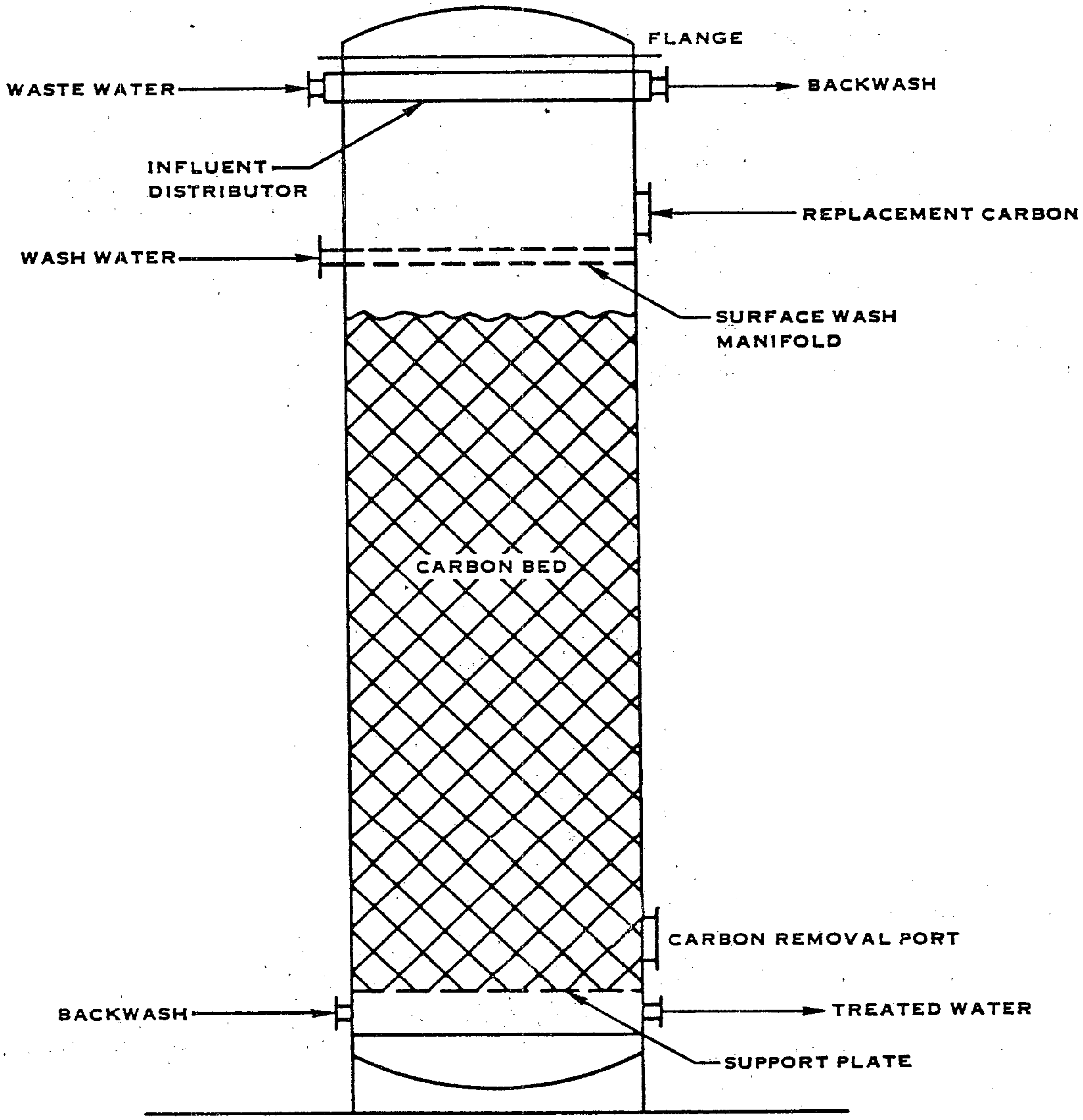


FIGURE VII - 17. ACTIVATED CARBON ADSORPTION COLUMN

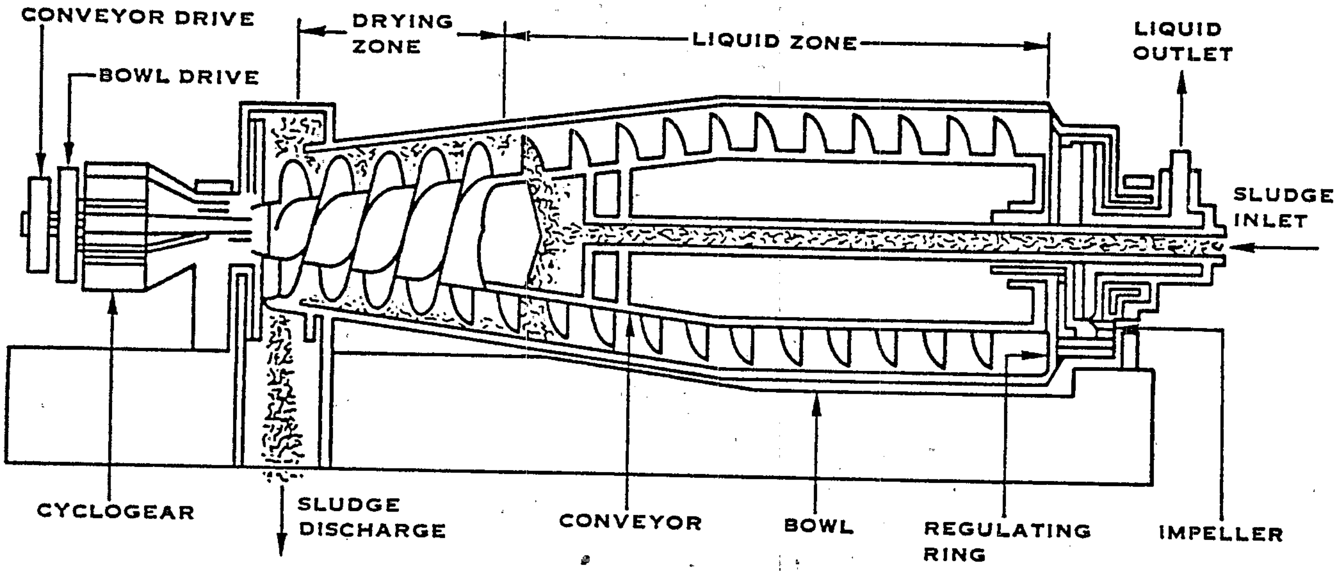


FIGURE VII - 18. CENTRIFUGATION

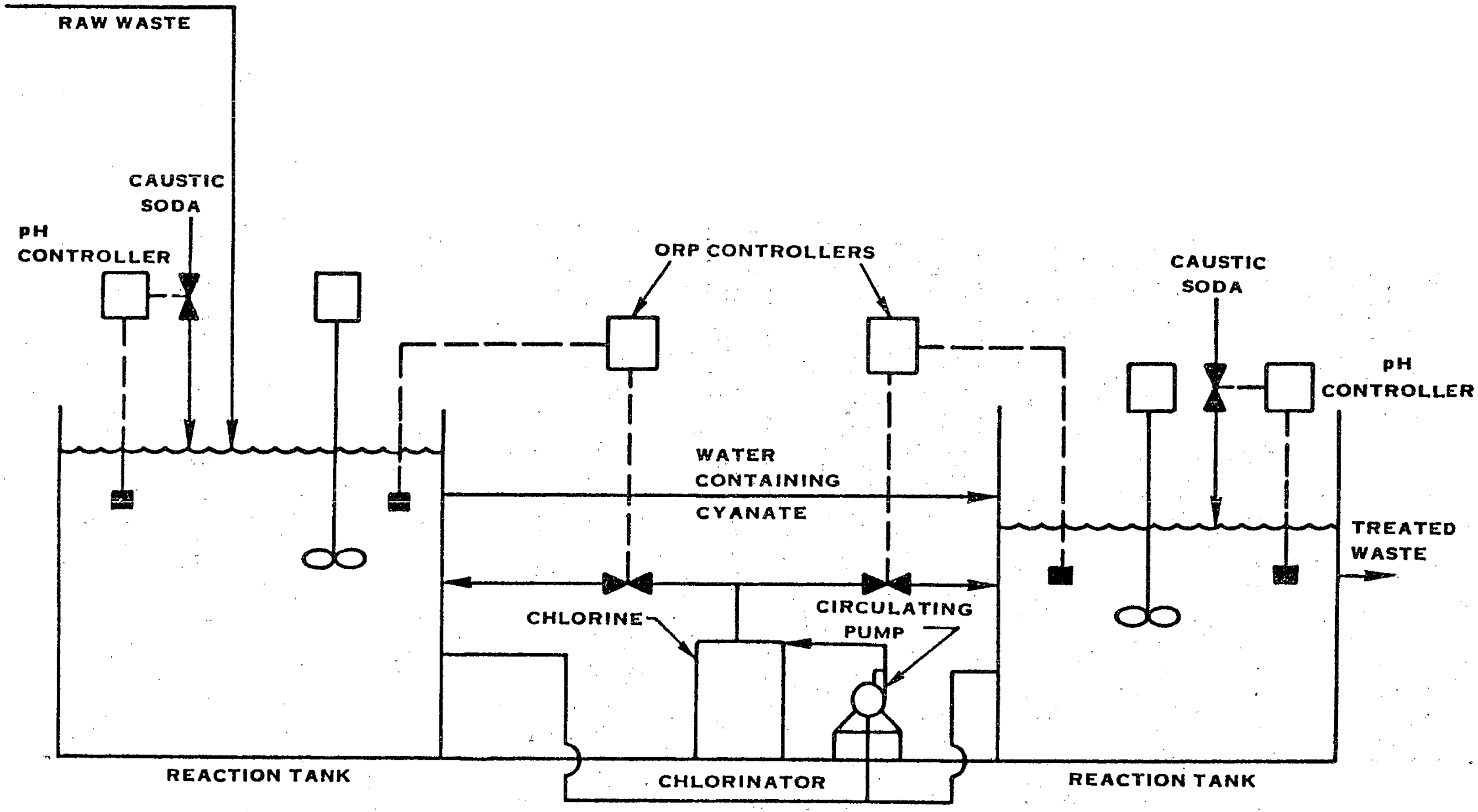


FIGURE VII - 19. TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION

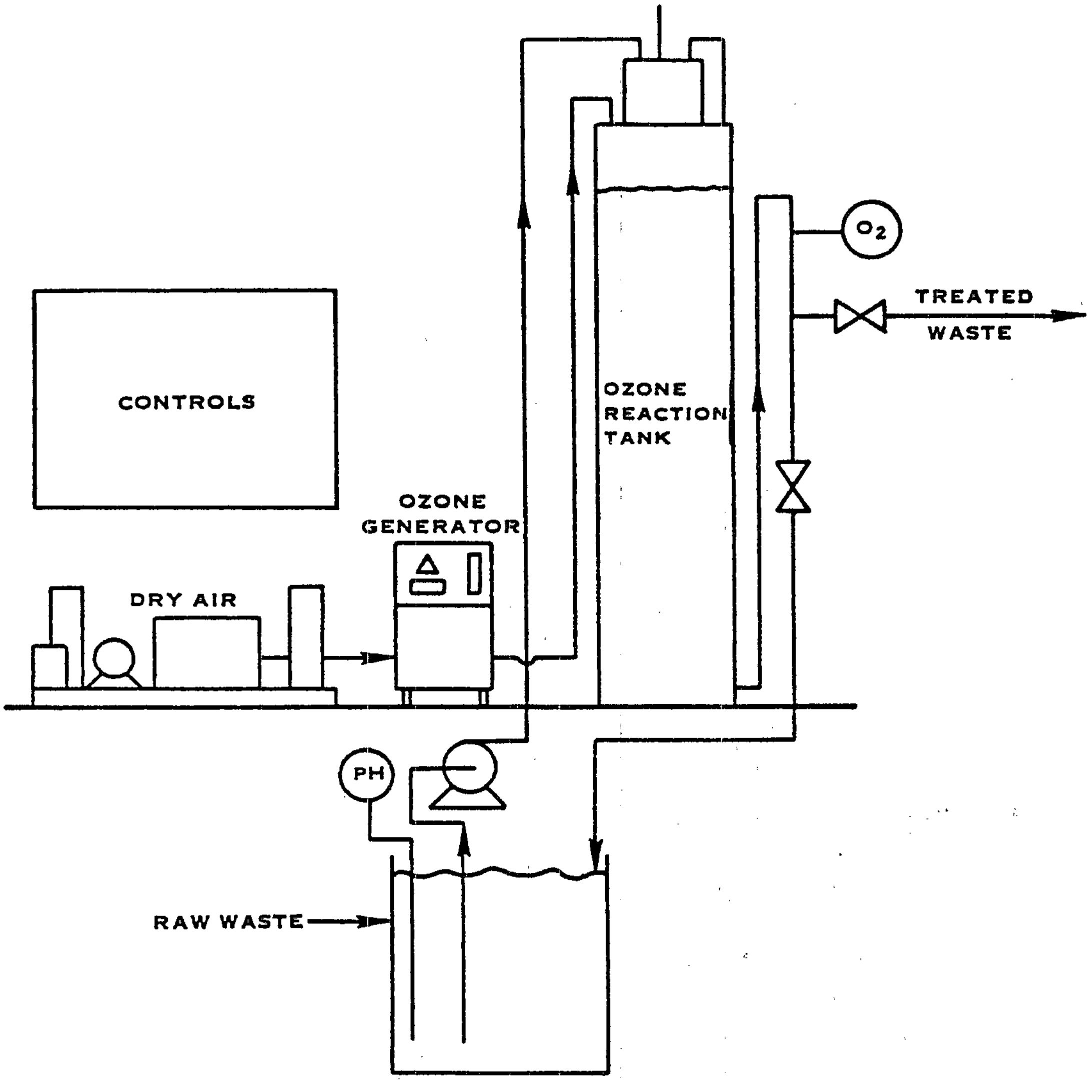


FIGURE VII - 20. TYPICAL OZONE PLANT FOR WASTE TREATMENT

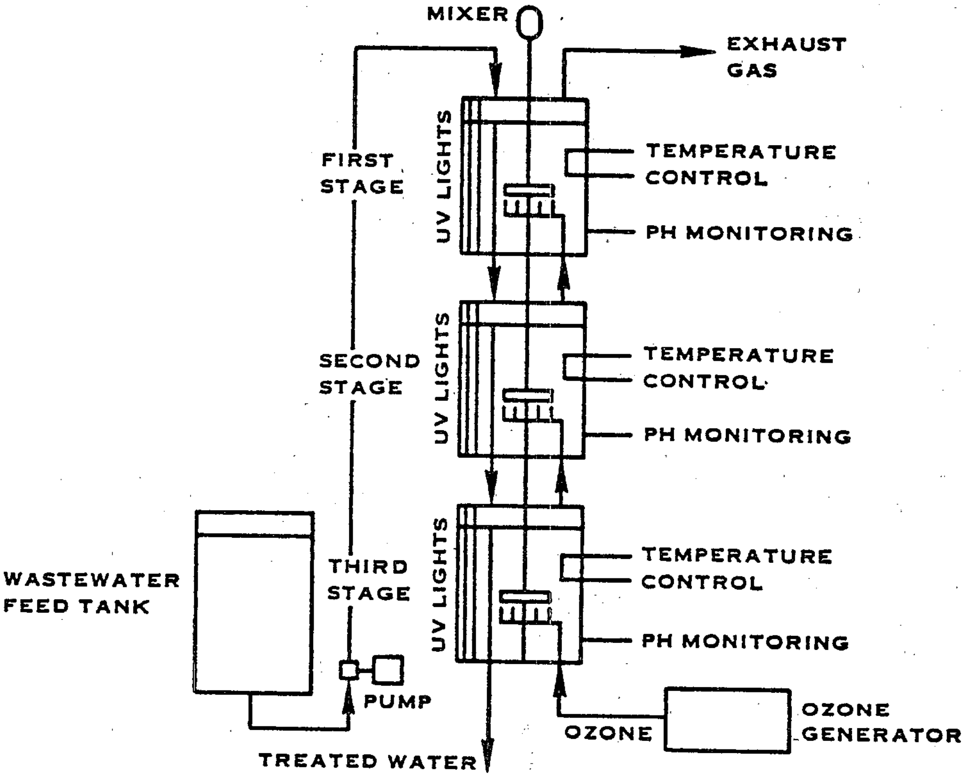
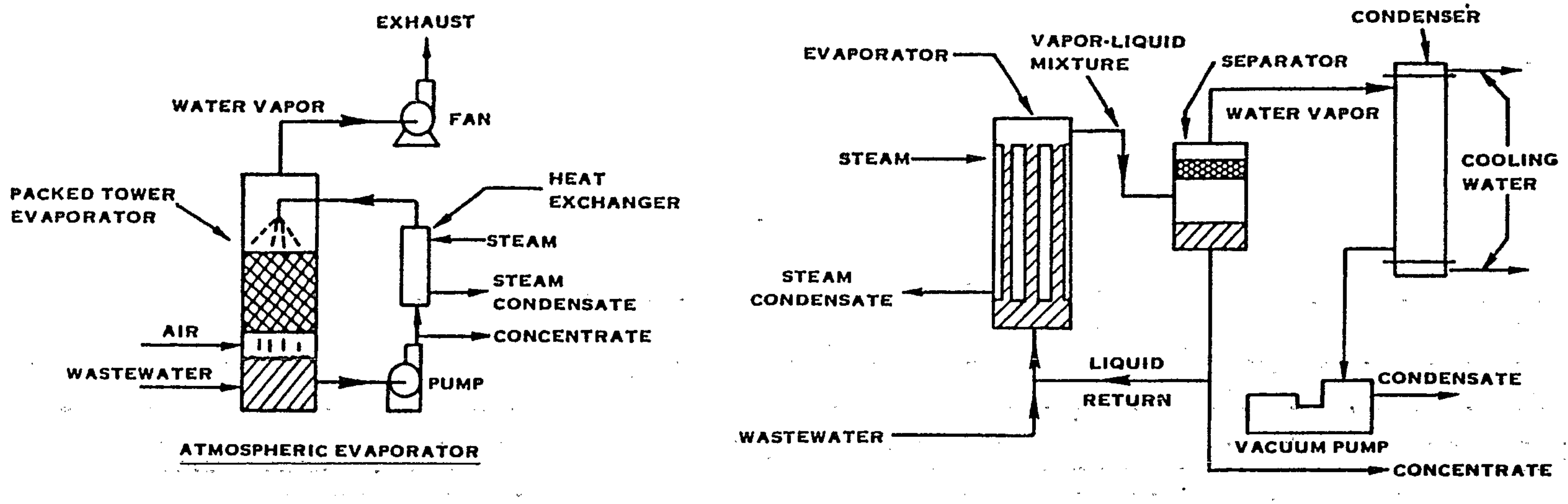
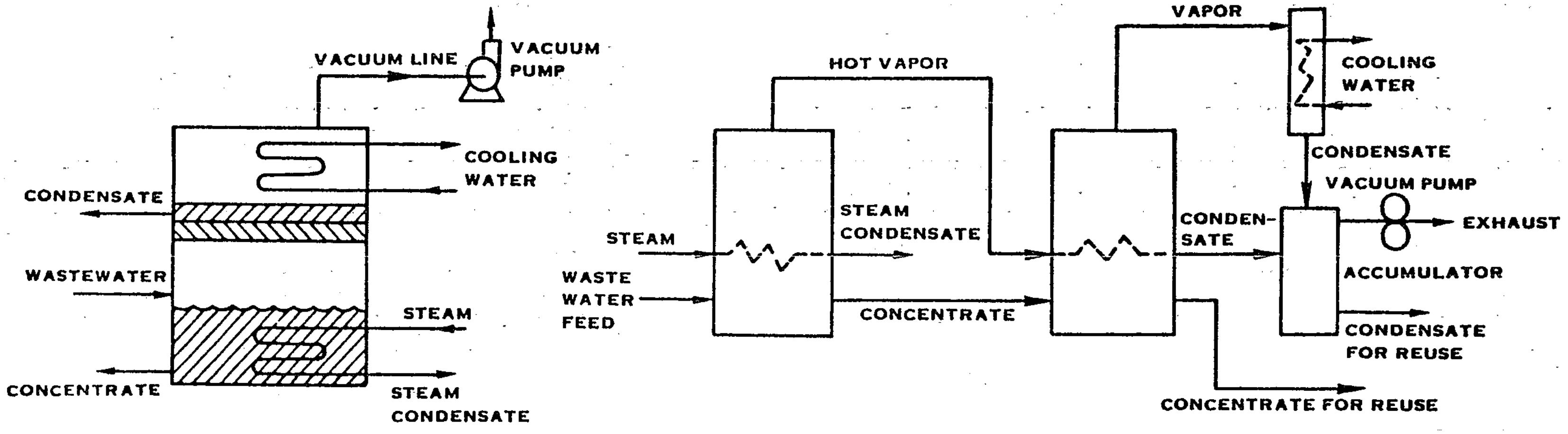


FIGURE VII-21. UV/OZONATION



ATMOSPHERIC EVAPORATOR

CLIMBING FILM EVAPORATOR



SUBMERGED TUBE EVAPORATOR

DOUBLE-EFFECT EVAPORATOR

FIGURE VII - 22. TYPES OF EVAPORATION EQUIPMENT

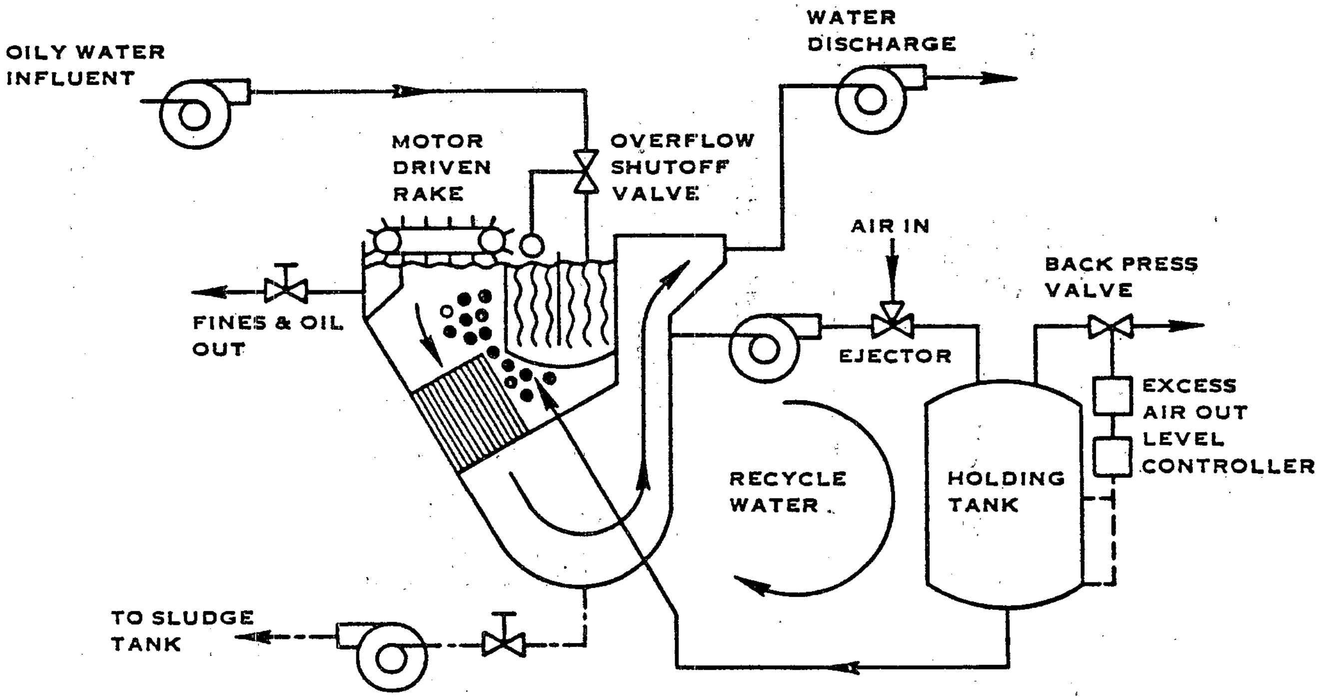
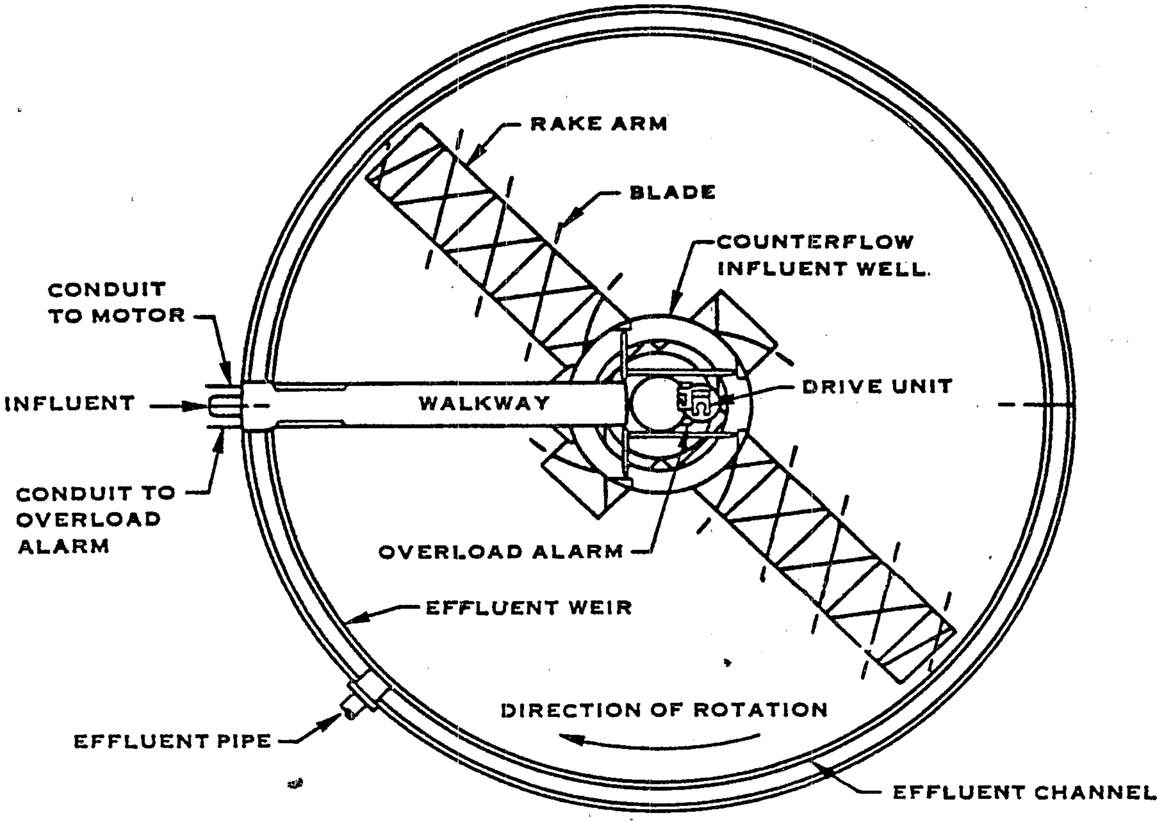


FIGURE VII - 23. DISSOLVED AIR FLOTATION



PLAN

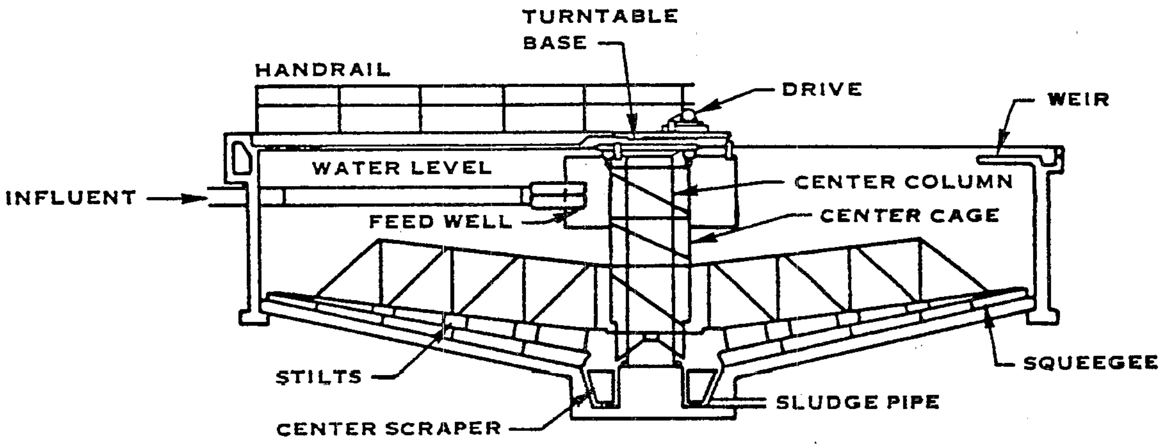


FIGURE VII - 24. GRAVITY THICKENING

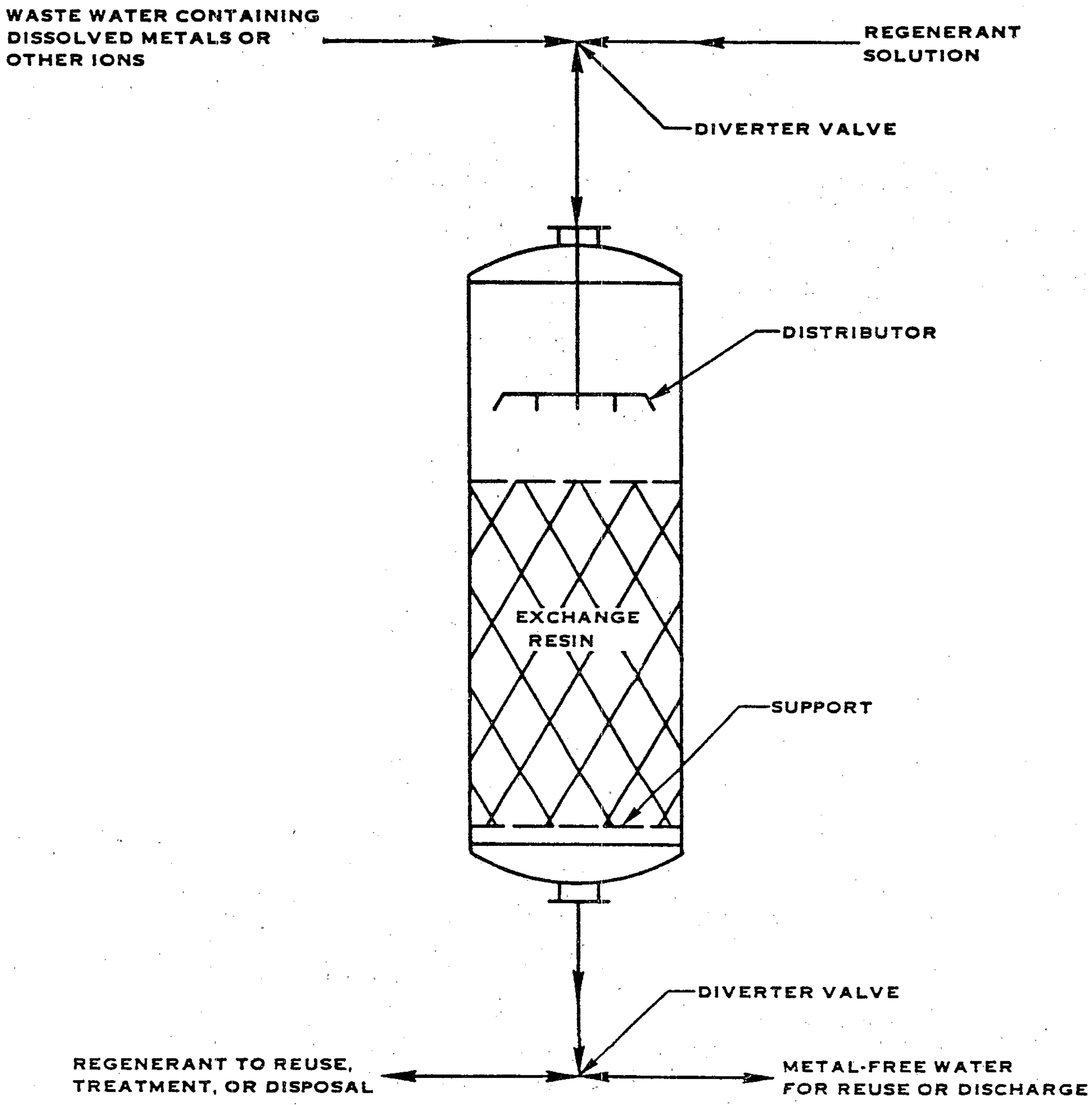


FIGURE VII - 25. ION EXCHANGE WITH REGENERATION

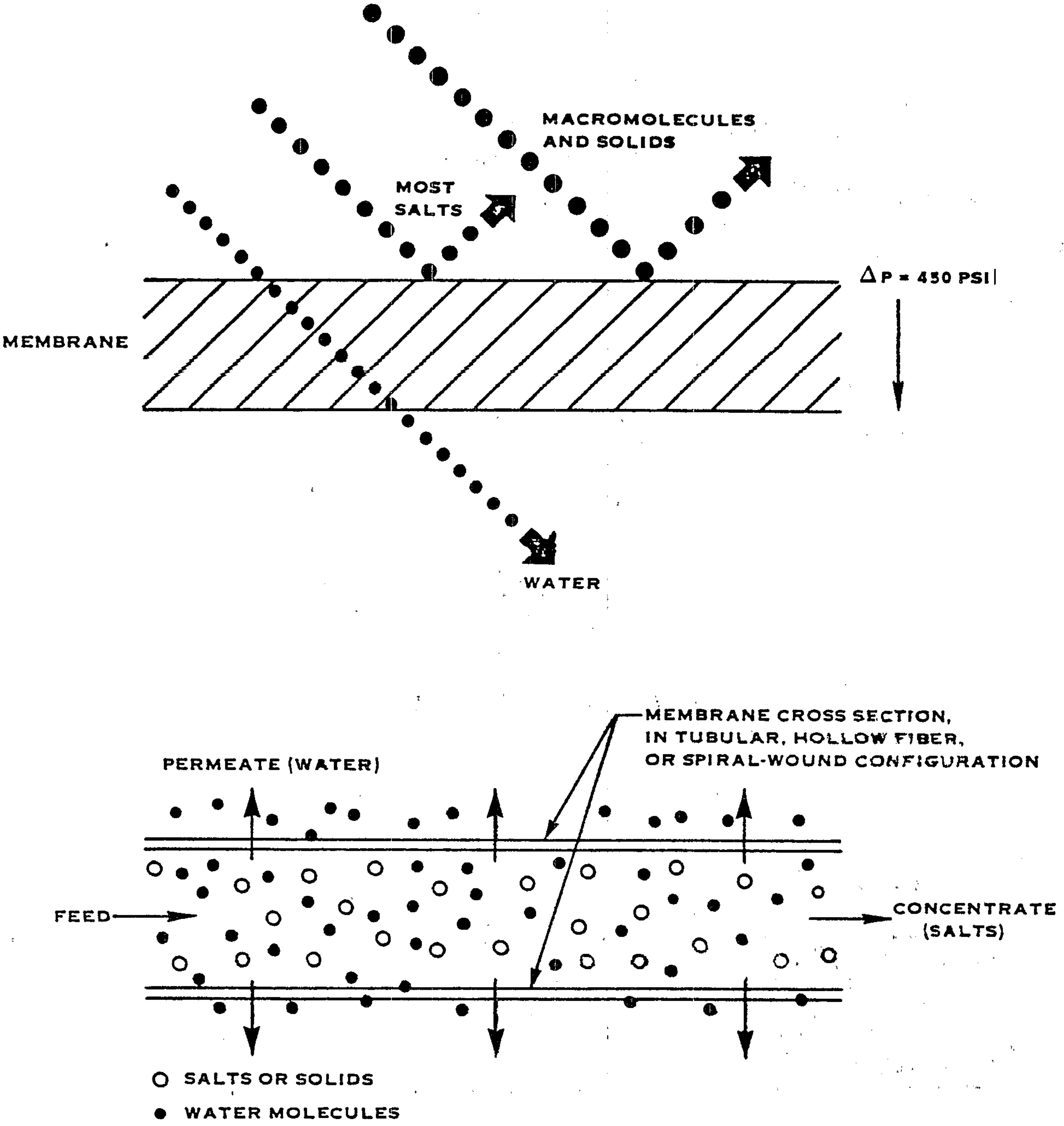
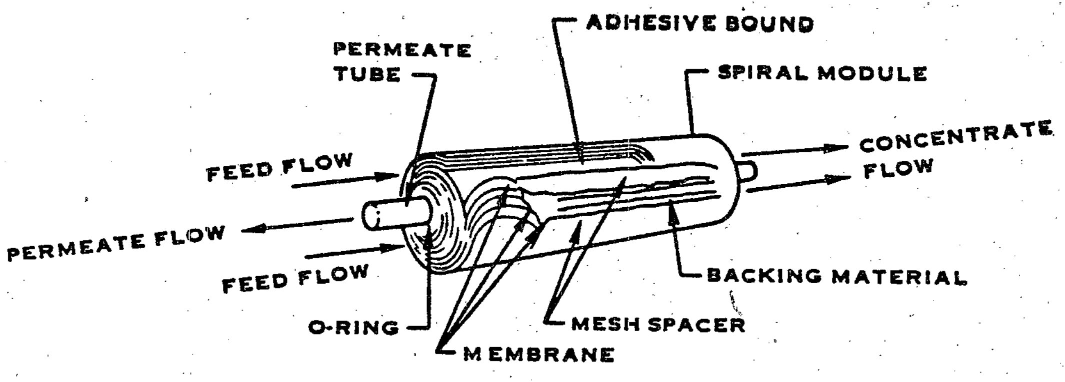
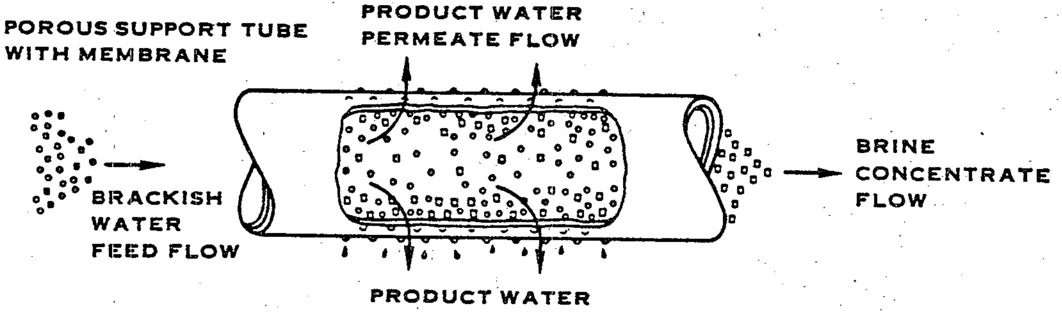


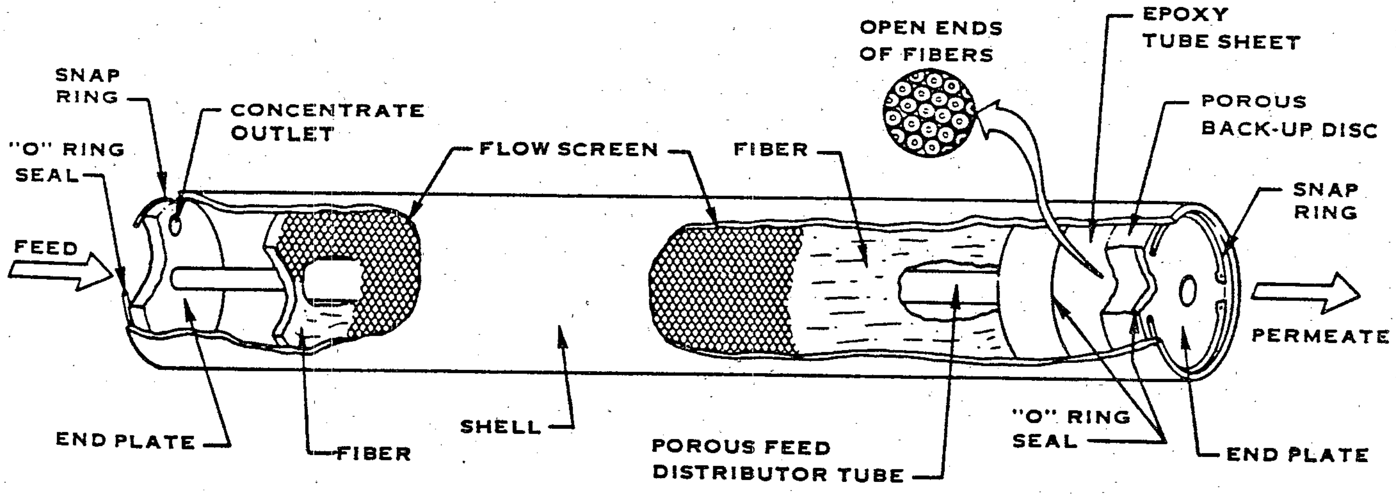
FIGURE VII - 26. SIMPLIFIED REVERSE OSMOSIS SCHEMATIC



SPIRAL MEMBRANE MODULE



TUBULAR REVERSE OSMOSIS MODULE



HOLLOW FIBER MODULE

FIGURE VII - 27. REVERSE OSMOSIS MEMBRANE CONFIGURATIONS

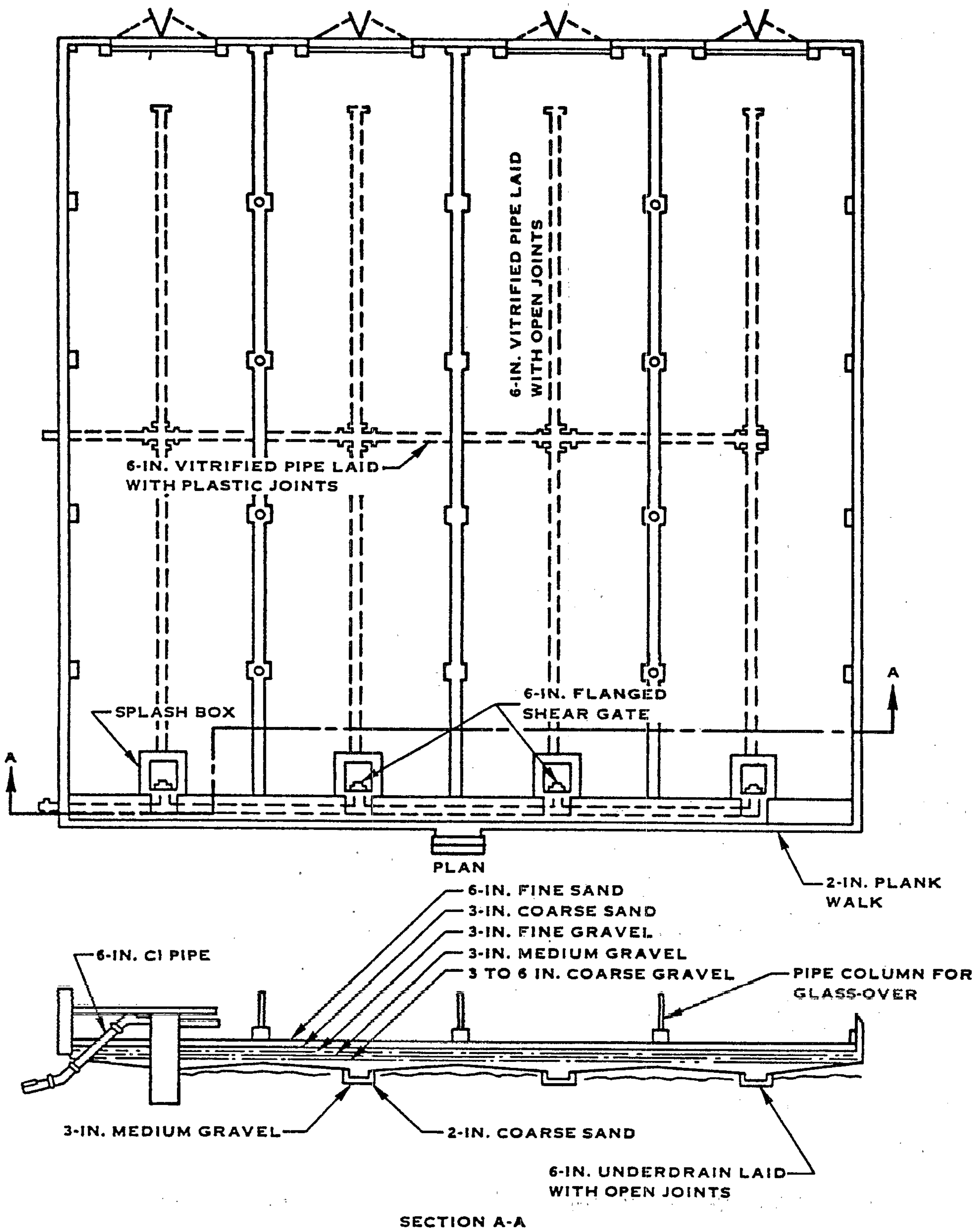


FIGURE VII - 28. SLUDGE DRYING BED

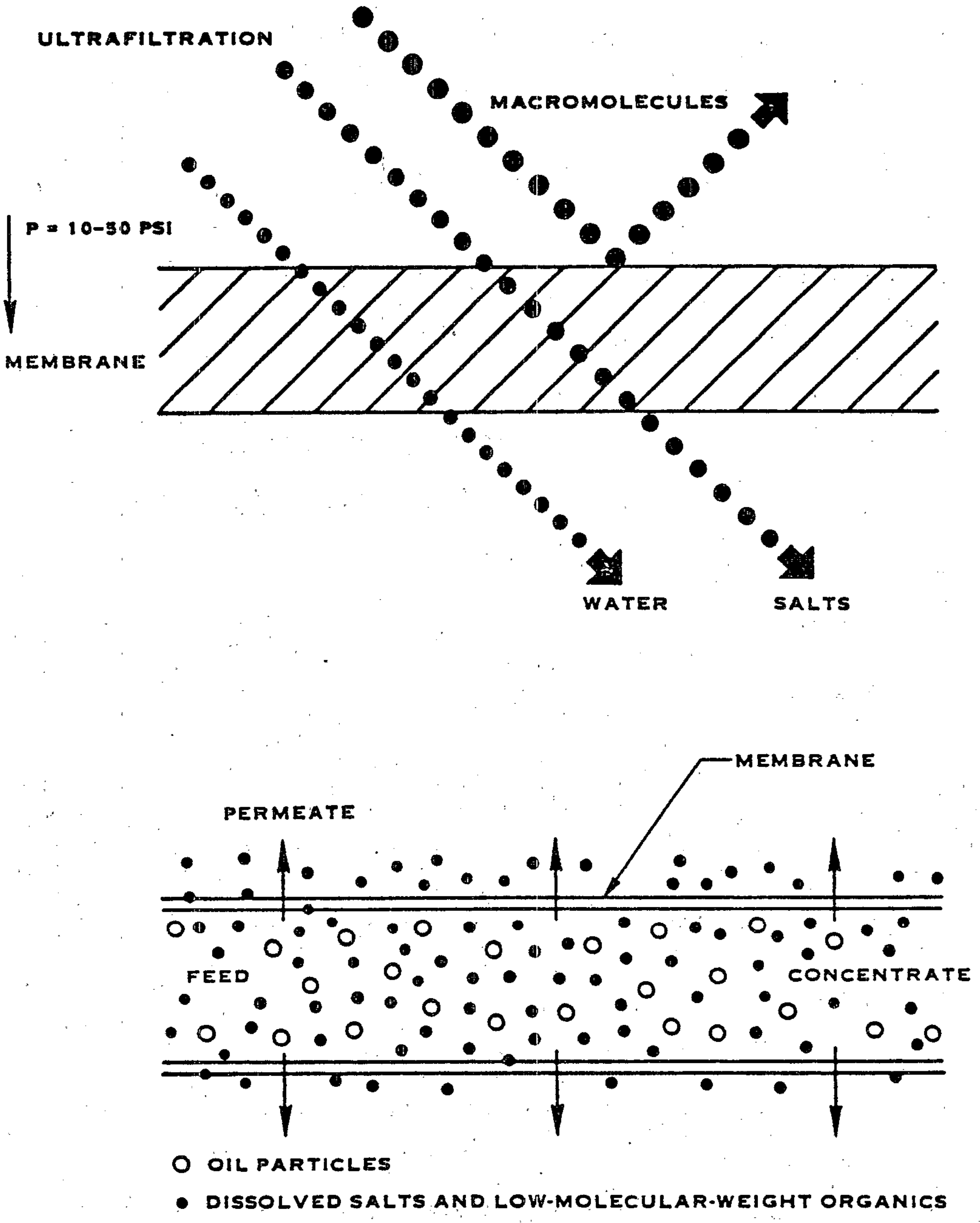


FIGURE VII - 29. SIMPLIFIED ULTRAFILTRATION FLOW SCHEMATIC

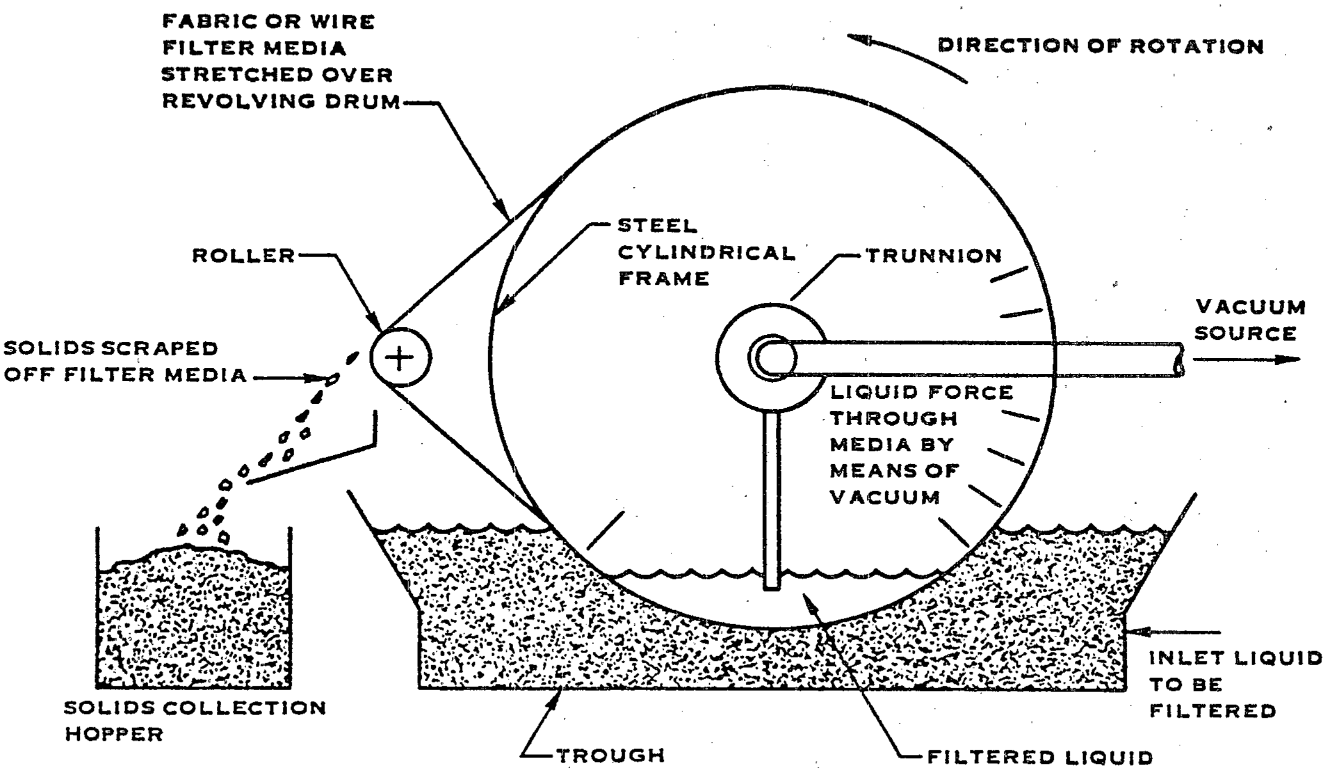


FIGURE VII - 30. VACUUM FILTRATION

SECTION VIII

COST OF WASTEWATER TREATMENT AND CONTROL

This section presents estimates of the costs of implementing the major wastewater treatment and control technologies described in Section VII. These cost estimates, together with the estimated pollutant reduction performance for each treatment and control option presented in Sections IX, X, XI, and XII, provide a basis for evaluating the options presented and identification of the best practicable technology currently available (BPT), best available technology economically achievable (BAT), best demonstrated technology (BDT), and the appropriate technology for pretreatment. The cost estimates also provide the basis for determining the probable economic impact on the battery manufacturing lead subcategory of regulation at different pollutant discharge levels. In addition, this section addresses nonwater quality environmental impacts of wastewater treatment and control alternatives, including air pollution, solid wastes, and energy requirements.

GENERAL APPROACH

Capital and annual costs associated with compliance with the lead subcategory limitations and standards have been calculated on a plant-by-plant basis for 85 discharging plants and extrapolated for 26 discharging plants in the subcategory for which little or no data were available.

These costs have been used as the basis for an economic impact analysis of the lead subcategory (See "Economic Impact Analysis of Effluent Limitations and Standards for the Battery Manufacturing Industry," EPA 440/2-84-002). For that analysis cost estimates were broken down for each facility producing lead batteries and cost results were expressed in dollars per pound of battery produced.

Prior to proposal, costs were generated using the cost estimation methodology described in the development document of the proposed regulation. Since proposal, a new computer model for estimating end-of-pipe wastewater treatment system costs was developed for this subcategory and several other point source categories with similarly treatable wastewaters. In addition, in-plant costing procedures were revised. Capital and annual costs have been recalculated for all plants in the lead subcategory using the new computer model and the revised in-plant cost procedures. Table VIII-1 (page 489) summarizes these costs for the lead subcategory. A comparison between the proposal costing methodology and revised costing methodology is provided later in this section.

COST ESTIMATION MODEL BASES

In this section, the end-of-pipe treatment system cost estimation models are presented for the lead subcategory. The assumptions for the cost model and the in-plant cost procedure may be found later in this section.

End-of-pipe compliance costs were estimated for each plant based on the wastewater sources with discharge allowances. The possible wastewater sources at each plant are double fill formation, fill and dump formation, open dehydrated formation, direct chill casting, mold release formulation equipment washdown, battery wash with detergent, battery wash with water, truck wash, laundry, battery repair, laboratory, floor wash, handwash, respirator wash, and wet air pollution control scrubbers. The last six streams were included in a miscellaneous group, providing the entire flow of all six streams if any one was present. Discharge allowances for plate soaking and open wet formation were provided after costs for the lead subcategory were determined. The flows from these areas are deminimus and do not affect the cost estimates.

The treatment trains presented in Figure IX-1 and Figures X-1 to X-4 were used as the basis for cost estimation. Plant-by-plant costs were determined for BPT and BAT (PSES) Options 1 and 2. Costs for BAT Options 3 and 4 were determined for a normal plant and a normal discharging plant. The normal and normal discharging plant are discussed later in this section. As shown in Figures X-1 to X-4, a holding tank, used for recycling wastewater back to the plant for use in hose washdown of equipment and floor areas, is part of the BAT (PSES) treatment train. Water is recycled after chemical precipitation and settling. An additional option, option 5, was considered for new sources only. The treatment train for this option is identical to option 2. For option 4 and option 5, the holding tank is also used for recycling treated water for truck washing.

Compliance costs for chemical precipitation were estimated using costs for lime addition. Sludge produced through lime precipitation is considered to be non-hazardous for the purposes of estimating costs. However, sludge generated from sulfide precipitation (normal plant only) is considered to be hazardous.

Miscellaneous wastewater has a smaller discharge allowance under BAT than under BPT. The difference is taken into account by the holding tank used to recycle water back to the plant for miscellaneous use (hose washdown) under the BAT (PSES) Options. Therefore, for the purposes of estimating compliance costs for BAT, the chemical precipitation and settling units are sized on the basis of the BPT flow with recycle occurring through the holding tank after chemical precipitation and settling. The BAT (PSES) flow is therefore equivalent to the final discharge flow and, for BAT (PSES)-2, multimedia filtration is sized on the basis of this flow. Since the flow into treatment for option 2 and the additional new source option (option 5) are nearly the same and the treatment train is the same, costs for these two options are equal. The only difference between options 2 and 5 is that the holding tank is also used to recycle water for truck washing.

The following points should also be noted: (1) all of the costed plants were given an allowance for miscellaneous wastewater, and (2) if the actual flow from a process at a plant was unknown, costs were estimated on the basis of regulatory flow.

Required capital costs are determined by considering the equipment and wastewater treatment system a plant currently has in-place (see page 485). In the lead subcategory, four general assumptions are made concerning treatment in-place: (1) if a plant currently operates chemical precipitation but does not use lime as the precipitating reagent, only the capital cost of the lime feed system is included under required capital. (2) If the plant reports sedimentation in lagoons, these are assumed to be used as impoundments for sludge storage. Therefore, no solids dewatering equipment is assumed to be required. To reflect the annual cost of operating the lagoon or pond and ultimate disposition of the sludge, the annual costs of a vacuum filter and contract hauling are included. In most cases, these costs are overestimated for actual operation of the lagoon or pond. (3) If a "sump" is reported to be in-place, it is assumed that it will not provide adequate equalization or be an adequate tank to operate chemical precipitation unless the sump volume is reported and determined to have sufficient capacity. If a "pit" is reported to be in-place, it is assumed that it will provide adequate equalization but will not be an adequate tank to operate chemical precipitation unless solids removal is reported. (4) If a plant currently has treatment for the continuous operation of chemical precipitation but compliance cost estimates are based on a batch system (i.e., flow less than 10,600 l/hr), required capital costs are determined through evaluation of the specifics of a plant's current treatment system including the type of precipitating reagent(s) added.

COST COMPARISON PROPOSAL VERSUS PROMULGATION

The costs estimated for the proposed regulation differ from those estimated under this final rule. These differences stem from different methodologies for estimation of costs for both in-plant control technology and end-of-pipe treatment technology.

In-Plant Changes

As discussed earlier in this section, the Agency has revised its lead subcategory in-plant cost procedures from proposal. In addition, in-plant cost procedures for five technologies have been added to the original in-plant procedures. The five new technologies are:

- Steam curing
- Humidity curing water recycle
- Formation area wet air pollution control (WAPC) water recycle
- Paste mixing WAPC water neutralization
- Power floor scrubber water settling.

Table VIII-2 (page 490) presents a summary of the in-plant cost procedure changes.

The major revision to the in-plant cost procedures was in slow formation. At proposal, slow formation costs included a building and racks for stacking batteries. During post-proposal site visits, sufficient vertical height was observed in existing buildings to provide the necessary stacking for slow formation. Erection of a new building is not required. Therefore, building costs were removed from the in-plant costs for slow formation. The Agency also revised its approach to plant-by-plant costing for slow formation. At proposal, slow formation was costed for all plants that reported a discharge from closed formation. For promulgation, slow formation was only costed for those plants that specified the use of contact cooling water in closed formation. The costs for reducing other wastewater flows from closed formation, such as battery rinse water, area washdown water, and wet air pollution control water are estimated using the appropriate in-plant cost procedures.

Another major revision to the in-plant cost procedures was to countercurrent cascade rinsing labor costs. For proposal, a $6.60 per manhour labor rate was used to determine labor costs.

The revised costs use a $21.00 per manhour labor rate. The proposal costs were developed assuming approximately 0.001 manhours per kilogram of lead use were required for countercurrent cascade rinsing labor. The revised costs assume 0.000169 manhours per kilogram of lead use are required for labor. This value is based on observations made during sampling visits. The revised costs are based on the incremental labor required for countercurrent cascade rinsing. This incremental labor is the labor needed to move plates from the first stage rinse tank to the second stage rinse tank. The proposal labor costs are based on a total labor requirement for running the countercurrent cascade rinse. This represents an overestimate of labor costs since plant personnel are already present to run the rinse operation. Also, a difference between the proposal labor costs and revised labor costs is an economy of scale factor. At proposal, labor costs were assumed to be a linear function of production. The revised labor costs account for the economy of scale associated with increasing production by relating labor costs to the six-tenths power of production.

Segregation costs have also been revised. Piping costs for segregation are included in the individual in-plant technology costs. A model-based segregation cost procedure was developed, however, for segregating nonprocess waste streams from process waste streams. For proposal, a segregation cost was estimated for routing wastewater to end-of-pipe treatment. This cost was based on a trench excavation cost and piping cost. The revised costs more accurately reflect the cost of segregating water flows.

End-of-Pipe Comparison

Because a different contractor developed compliance cost estimates for the final regulation, a different computer model was used for cost estimation than was used for the proposed regulation. As such, the cost estimates reflected the assumptions and design and cost data upon which each model was based. As can be seen from Table VIII-3 (page 493), the annual costs for BPT under this final rule were higher than at proposal, while the capital costs were lower. For either BAT (PSES) option, both annual and capital costs were lower for this final rule. The increase in BPT annual costs are due primarily to differing assumptions for labor rate, labor requirements, and contract hauling costs; also, additional analytical data have been collected since proposal that will result in differing compliance costs. Further, a 10 percent interest rate for capital recovery was used for cost estimation at proposal while a 12 percent interest rate was used for this regulation. Each of these were found to increase annual costs for BPT.

The decrease in annual costs for the BAT options probably results from the procedure for estimating flows to the treatment system. Rather than actual flow reported by each plant, the cost estimation model discussed in this section calculated flow by comparing the actual flow for each process element with the regulatory flow for that element, and then selecting the lower value as the flow to treatment.

The models also differed in specific assumptions for each module. The assumptions for the model used at proposal are documented in a report entitled "Comparison of Cost Methodologies for EGD - Metals and Machinery Branch." This report is included in the public record supporting this regulation.

COST ESTIMATION METHODOLOGY: POST-PROPOSAL

The calculation of plant-by-plant costs consists of two steps. In-plant flow reduction costs are calculated using the in-plant cost procedures, and treatment system (end-of-pipe) costs are calculated using the computer model. Sources of cost data, components of capital and annual costs, and cost update factors are similar for the two costing procedures. A general discussion on the sources of cost data, components of costs, and cost update factors is presented below. Following these discussions the in-plant cost procedures and computer model are discussed.

Sources of Cost Data

Capital and annual cost data for the selected treatment processes were obtained from three sources: (1) equipment manufacturers, (2) literature data, and (3) cost data from existing plants. The major source of equipment costs was contacts with equipment vendors, while the majority of annual cost information was obtained from the literature. Additional cost and design data were obtained from data collection portfolios when possible.

Components of Costs

Capital Costs. Capital costs consist of two components: equipment capital costs and system capital costs. Equipment costs include: (1) the purchase price of the manufactured equipment and any accessories assumed to be necessary; (2) delivery charges, which account for the cost of shipping the purchased equipment a distance of 500 miles; and (3) installation, which includes labor, excavation, site work, and materials. The correlating equations used to generate equipment costs are shown in Table VIII-4 (page 494).

Capital system costs include contingency, engineering, and contractor's fees. These system costs, each expressed as a percentage of the total equipment cost, are combined into a factor which is multiplied by the total equipment cost to yield the total capital investment. The components of the total capital investment are listed in Table VIII-5 (page 500).

Annual Costs. The total annualized costs also consist of a direct and a system component as in the case of total capital costs. The components of the total annualized costs are listed in Table VIII-6 (page 501). Direct annual costs include the following:

o Raw materials - These costs are for chemicals used in the treatment processes, which include lime, sulfuric acid, alum, polyelectrolyte, and sulfur dioxide.

o Operating labor and materials - These costs account for the labor and materials directly associated with operation of the process equipment. Labor requirements are estimated in terms of manhours per year. A labor rate of 21 dollars per manhour was used to convert the manhour requirements into an annual cost. This composite labor rate included a base labor rate of nine dollars per hour for skilled labor, 15 percent of the base labor rate for supervision and plant overhead at 100 percent of the total labor rate. Nine dollars per hour is the Bureau of Labor national wage rate for skilled labor during 1982.

o Maintenance and repair - These costs account for the labor and materials required for repair and routine maintenance of the equipment.

o Energy - Energy, or power, costs are calculated based on total nominal horsepower requirements (in kw-hrs), an electricity charge of $.0483/kilowatt-hour and an operating schedule of 24 hours/day, 250 days/year unless specified otherwise. The electricity charge rate (March 1982) is based on the industrial cost derived from the Department of Energy's Monthly Energy Review.

System annual costs include monitoring, insurance and amortization (which is the major component). Monitoring refers to the periodic sampling analysis of wastewater to ensure that discharge limitations are being met. The annual cost of monitoring was calculated using an analytical lab fee of $120 per wastewater sample and a sampling frequency based on the wastewater discharge rate, as shown in Table VIII-7 (page 502).

Insurance cost is assumed to be one percent of the total depreciable capital investment (see Item 23 of Table VIII-6).

Amortization costs, which account for depreciation and the cost of financing, were calculated using a capital recovery factor (CRF). A CRF value of 0.177 was used, which is based on an interest rate of 12 percent, and a taxable lifetime of 10 years. The CRF is multiplied by the total depreciable investment to obtain the annual amortization costs (see Item 24 of Table VIII-6).

Cost Update Factors

All costs are standardized by adjusting to June of 1983. This was done by updating the model costs (which are calculated in March 1982 dollars) using the EPA-Sewage Treatment Plant Construction Cost Index. The June 1983 value of this index is 420.6. The cost indices used for particular components of costs are described below.

Capital Investment - Investment costs were adjusted using the EPA-Sewage Treatment Plant Construction Cost Index. The value of this index for March 1982 is 414.0.

Operation and Maintenance Labor - The Engineering News-Record Skilled Labor Wage Index is used to adjust the portion of Operation and Maintenance costs attributable to labor. The March 1982 value is 325.0.

Maintenance Materials - The producer price index published by the Department of Labor, Bureau of Statistics is used. The March 1982 value of this index is 276.5.

Chemicals - The Chemical Engineering Producer Price Index for industrial chemicals is used. This index is published biweekly in Chemical Engineering magazine. The March 1982 value of this index is 362.6.

Energy - Power costs are adjusted by using the price of electricity on the desired date and multiplying it by the energy requirements for the treatment module in kwhr equivalents.

In-Plant Costs

In-plant flow reduction cost procedures were developed for the following lead subcategory process elements and ancillary activities:

(1) Paste mixing and application area wash water recycle

(2) Steam curing

(3) Humidity curing water recycle

(4) Slow formation

(5) Open dehydrated formation water
    - Countercurrent cascade plate rinsing
    - Vacuum pump seal and ejector water recycle

(6) Formation area wet air pollution control (WAPC) water recycle

(7) Paste mixing WAPC water neutralization

(8) Reuse of battery rinse water in acid cutting

(9) Power floor scrubber water settling

(10) Hose washdown water recycle

(11) Segregation on nonprocess water flows.

Table VIII-8 (page 503) summarizes the number of plants that were costed using each of the above in-plant technologies. The hose washdown water recycle costs were estimated by the end-of-pipe cost estimation model. A brief discussion on the in-plant cost procedure is presented in this section. A detailed discussion which includes all design assumptions and a derivation of all in-plant cost equations is presented in the battery manufacturing public record.

All in-plant costs were developed in a similar manner. The costs for implementing each technology were first determined for a model plant. Using the model plant flow and production, equipment items required for the in-plant technology were sized. Equipment costs were then determined using the cost equations contained in the public record. The model plant production, and capital and annual operating and maintenance costs (O&M costs) were then used to develop a general algorithm for determining the cost for any size battery manufacturing operation. The general algorithm was the standard "six-tenths" scaling factor. Figures VIII-1 to VIII-12 (pages 509 to 520) summarize the equipment capital and direct annual costs for each in-plant technology. No credit was given in the in-plant costs for savings due to the lower water usage that results when the various in-plant technologies are used.

The following presents a summary of the development of equipment capital and direct annual costs for each in-plant technology. This discussion includes the methodology used to identify the in-plant technologies applicable for a given plant.

Paste Mixing and Application Area Wash Water Recycle. As discussed in Section VII, the recycle of pasting area wash water after settling for suspended solids removal is practiced by a number of plants in the lead subcategory. Figure VIII-1 shows the equipment capital and direct annual costs associated with installing a recycle system for pasting area wash water. The recycle system costs are based on the cost for installing a three stage settling system, a holding tank for retaining the settled water before reuse, piping for segregation, and two pumps.

Pasting area water recycle costs were determined for both BPT and BAT (PSES). The recycle system costs were estimated for all plants that discharge pasting area wash except those that had recycle equipment in place.

Steam Curing. Some plants continuously discharge condensate from steam curing. As discussed in Section VII, it is feasible to utilize steam curing without incurring a discharge by implementing one of a variety of techniques. For plants that currently discharge this stream, a cost was determined for converting to zero discharge. The cost model basis selected includes the addition of pressure relief valves to vent the steam. Figure VIII-2 shows the equipment capital cost associated with installing the pressure relief valves. There are no direct annual costs associated with the zero discharge operation. The steam curing costs were estimated for both BPT and BAT (PSES).

Humidity Curing Water Recycle. Some plants report a continuous discharge from humidity curing operations. For plants which report this discharge, an external water recycle system was costed for BPT and BAT (PSES). The water recycle system equipment includes a holding tank, one pump, piping for segregation, and a collection trench for the curing water. Figure VIII-3 shows the equipment capital and direct annual costs for the water recycle system.

Slow Formation. As discussed in Section VII, some plants which charge batteries at high amperage (fast formation) require the use of cooling water since they generate significant quantities of heat. One technology for eliminating the use of cooling which can be costed is slow formation. Figure VIII-4 shows the equipment capital costs for converting to slow formation. The slow formation capital costs are based on the installation of racks for stacking batteries (as opposed to charging on tables) and a retrofit cost for converting from fast formation to slow formation. Direct annual costs are not affected by converting from fast formation to slow formation.

Slow formation was costed for BAT (PSES) for all plants that reported a cooling water discharge from double fill or fill and dump formation. For plants that report a cooling water discharge from single fill formation, slow formation was costed for BPT and BAT (PSES).

Open Dehydrated Formation Water. Wastewater discharge from open dehydrated formation is associated with rinsing formed plates. At some plants, wastewater is also discharged from vacuum pump seals and ejectors used for dehydrating the rinsed plates. The wastewater discharge from plate rinsing can be greatly reduced if the plates are rinsed with countercurrent cascade techniques, with flow controllers and agitation.

Figure VIII-5 shows the equipment capital cost associated with countercurrent cascade rinsing. These costs are based on converting from a single stage rinse to a two stage countercurrent cascade rinse. The countercurrent cascade rinsing costs include installation of an additional rinse tank, a flow control system, piping, and air spargers for air agitation. The rinse tanks are agitated to ensure proper mixing. Air agitation is accomplished by bubbling compressed air through the air spargers. The air agitation costs assume that a source of compressed air is already in-place. The flow control system consists of a conductivity flow controller and a motorized butterfly valve.

Figure VIII-5 also shows the incremental labor (direct annual cost) for using a two stage countercurrent cascade rinse instead of a single stage rinse. This cost is for the incremental labor associated with moving the plates from the first stage to the second stage of the rinse tanks.

Figure VIII-6 shows the equipment capital and direct annual costs associated with recycling wastewater from vacuum pump seals and ejectors (sealant water recycle). Since the level of contamination in waste streams from this source is low, recycle will drastically reduce the high volume discharges presently produced at some facilities. The sealant water recycle costs are based on the installation of a holding tank, one pump, and piping for segregation.

Costs for BAT (PSES) only were estimated for countercurrent cascade rinsing and sealant water recycle. A number of different costing situations were encountered when estimating these flow reduction costs. These situations and the costing procedure followed for each situation are discussed below:

1. Plant Reports Discharge From Both Plate Rinsing and Sealant Water Which is Greater than BAT (PSES) Regulatory Flow for Open Dehydrated Formation -- In this situation both countercurrent cascade rinsing and sealant water recycle were costed.

2. Plant Reports Discharge from Plate Rinsing Only Which is Greater Than BAT (PSES) Regulatory Flow for Open Dehydrated Formation -- In this situation only countercurrent cascade rinsing was costed.

3. Plant Reports Discharges from Both Plate Rinsing and Sealant Water But Does Not Report Flow -- In this situation both sealant water recycle and countercurrent cascade rinsing were costed.

4. Plant Reports Discharge from Plate Rinsing Only But Does Not Report Flow -- In this situation countercurrent cascade rinsing was costed.

5. Plant Reports Discharge Flow from Open Dehydrated Formation Which is Greater Than BAT (PSES) Regulatory Flow But Does Not Indicate Where Flow is From -- In this situation it was assumed that the flow was from plate rinsing only and countercurrent cascade rinsing was costed.

6. Plant Reports Discharge From Open Dehydrated Formation But Does Not Report the Flow or Where the Flow is From -- In this situation, countercurrent cascade rinsing was costed.

<u>Formation Area Wet Air Pollution Control Water Recycle</u>. Wet air pollution control (WAPC) scrubbers are used in the formation area to primarily remove acid fumes generated during formation. The discharge flow from these scrubbers can be minimized if the scrubber water is neutralized with caustic and recycled. Figures VIII-7 and VIII-8 show the equipment capital and direct annual costs associated with recycle formation area WAPC water. The recycle system costs include a holding tank, agitator, one pump, piping for segregation, and a caustic addition system (instrumentation for pH control, and a caustic storage tank). The caustic storage tank is mounted on the holding tank so that caustic can be gravity fed through a small valve into a holding tank.

Formation area WAPC recycle costs were estimated for BPT and BAT (PSES) for all plants that reported a discharge from formation area WAPC scrubbers in excess of 0.006 l/kg. These costs were also estimated for plants which did not report their formation area WAPC flow.

Paste Mixing WAPC Water Neutralization. An annual cost was estimated at BPT and BAT (PSES) for any plants which reported a flow greater than 0.005 l/kg. The model used to establish the cost basis is a rotoclone-type scrubber. The flow is based on semi-annual dumping of the scrubber water. A cost of $100 per plant per year was assigned to all plants which reported a discharge flow which exceeded the criterion. This cost was also assigned to plants which reported a discharge but did not report the flow value. The cost is for addition of caustic to the rotoclone tank for acid neutralization to prevent corrosion.

Reuse of Battery Rinse Water in Acid Cutting. Battery rinse water is used for product rinses in the formation areas and battery wash with water only.

As discussed in Section VII, all water used in a properly operated battery rinse can be reused to dilute (cut) acid to the appropriate specific gravity for battery electrolyte. Proper operation is where water is recycled at the rinse station and flows only when batteries are present. Figures VIII-9 and VIII-10 show the equipment capital and direct annual costs associated with reusing battery rinse water in acid cutting. The equipment includes a holding tank, two pumps, piping for segregation, and a photoelectric eye. The photoelectric eye activates the battery rinse flow when a battery passes beneath it. The eye deactivates the flow after the last battery is rinsed.

Reuse of battery rinse water in acid cutting costs were estimated for BAT (PSES). For costing purposes, it was assumed that plants with formation battery rinses operate a detergent battery wash, where the final rinse is used as makeup to the detergent recycle. Several plants had equipment in-place to reuse battery rinse water; no costs were estimated for these plants.

Power Floor Scrubber Water Settling. Wastewater from power floor scrubbers contains high concentrations of suspended solids and should be settled before treatment. Figure VIII-11 shows the equipment capital and direct annual costs for power floor scrubber water settling. These settling costs were estimated for BPT and BAT (PSES) for all plants that discharge wastewater. The floor scrubbing water settling equipment includes a settling tank, one pump, and piping. A labor cost for periodic tank cleaning is included in the O&M costs.

Segregation. Many plants discharge nonprocess streams to wastewater treatment. These nonprocess streams are not contaminated and can be either directly discharged or discharged to the sanitary sewer. Costs for segregation, or rerouting, of nonprocess water were estimated for all discharging plants for both BPT and BAT (PSES). Figure VIII-12 shows the equipment capital and direct annual costs associated with segregating nonprocess water.

As with other in-plant costs, the segregation costs were developed based on a model plant. The following equipment items were included in the model costs:

- Piping for routing each nonprocess stream to a common sump
- One sump with a level controller
- Piping for routing the combined nonprocess streams from the sump to the sanitary sewer or direct discharge
- One pump for pumping the water from the sump to the sanitary sewer or direct discharge.

There are a variety of nonprocess streams present at battery manufacturing plants. Table VIII-9 presents the disposition of nonprocess water among the plants visited in the post-proposal data collection period.

The segregation model costs are based on rerouting deionizer blowdown water, water softener backflush, and assembly area non-contact cooling water. The remaining nonprocess streams are already segregated by most plants.

Cost Estimation Model

Cost estimation was accomplished using a computer model which accepts inputs specifying the required treatment system chemical characteristics of the raw waste streams, flow rates and treatment system entry points of these streams, and operating schedules. This model utilizes a computer-aided design of a wastewater treatment system containing modules that are configured to reflect the appropriate equipment at an individual plant. The model designs each treatment module and then executes a costing routine that contains the cost data for each module. The capital and annual costs from the costing routine are combined with capital and annual costs for the other modules to yield the total costs for that regulatory option. The process is repeated for each regulatory option.

Each module was developed by coupling theoretical design information from the technical literature with actual design data from operating plants. This permits the most realistic design approach possible to be used, which is important to accurately estimate costs. The fundamental units for design and costing are not the modules themselves but the components within each module, e.g., the lime feed system within the chemical precipitation module. This is a significant for two reasons. First, it does not limit the model to certain fixed relationships between various components of each module. For instance, cost data for chemical precipitation systems are typically presented graphically as a family of curves with lime (or other alkali) dosage as a parametric function. The model, however, sizes the lime feed system as a function of the required mass addition rate (kg/hr) of lime. The model thus selects a feed system specifically designed for that plant. Second, this approach more closely reflects the way a plant would actually design and purchase its equipment. Thus, resulting costs are close to the actual costs that would be incurred by the plant.

<u>Overall Structure</u>. The cost estimation model consists of two main parts: a design portion and a costing portion. The design portion uses input provided by the user to calculate design parameters for each module included in the treatment system. The design parameters are then used as input to the costing routine, which contains cost equations for each discrete component in the system. The structure of the program is such that the entire system is designed before any costs are estimated.

The pollutants or parameters which are tracked by the model are shown in Table VIII-10 (page 505).

An overall logic diagram of the computer programs is depicted in Figure VIII-13 (page 521). First, constants are initialized and certain variables such as the modules to be included, the system configuration, plant and wastewater flows, compositions, and entry points are specified by the user. Each module is designed utilizing the flow and composition data for influent streams. The design values are transmitted to the cost routine. The appropriate cost equations are applied, and the module costs and system costs are computed. Figures VIII-14 and VIII-15 (pages 522 and 523) depict the logic flow diagrams in more detail for the two major segments of the program.

<u>Input Data Requirements</u>. Several data inputs are required to run the computer model. First, the treatment modules to be costed and their sequence must be specified. Next, information on hours of operation per day and number of days of operation per year for the particular plant being costed is required. The flow values

and characteristics must be specified for each wastewater stream entering the treatment system, as well as each stream's point of entry into the wastewater treatment system. These values then dictate the size and other parameters of equipment for which costs are to be determined. The derivation of each of these inputs for costed plants in the lead subcategory are discussed below.

Choice of the appropriate modules and their sequence for a costed plant are determined by applying the treatment technology for each option (see Figures IX-1 and X-1 through X-4). These option diagrams were adjusted to accurately demonstrate the treatment equipment that the costed plant will actually require. If a plant has a particular treatment module in place, that cost for that module will be determined. The information on hours of operation per day and days of operation per year was obtained from the data collection portfolio of the costed plant.

The flows used to size the treatment equipment were derived as follows: production (kg/yr) and flow (l/yr) information was obtained from dcp, or trip report data where possible, and a production normalized flow in liters per kilogram was calculated for each waste stream. This flow was compared to the regulatory flow, also in liters per kilogram, and the lower of the two flows was used to size the treatment equipment. Regulatory flow was also assigned to any stream for which production or flow data was not reported in the dcp.

The raw waste concentrations of influent waste streams used for costing were based on sampling data and the assumption that the total pollutant loading (mg/l) in a particular waste stream is constant, regardless of flow.

Model Results. For a given plant, the model generates comprehensive material balances for each parameter (pollutant, temperature and flowrate) at any point in the system. It also summarizes design values for key equipment in each treatment module, and provides a tabulation of costs for each piece of equipment in each module, module subtotals, total equipment costs, and system capital and annual costs.

Cost Estimates for Individual Treatment Technologies

Introduction. Treatment technologies have been selected from among the larger set of available alternatives discussed in Section VII after considering such factors as raw waste characteristics, typical plant characteristics (e.g., location, production schedules, product mix, and land availability), and present treatment practices. 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.

The specific assumptions for each wastewater treatment module are listed under the subheadings to follow. Costs are presented as a function of influent wastewater flow rate except where noted in the unit process assumptions.

Costs are presented for the following control and treatment technologies:

- Lime Precipitation and Gravity Settling,
- Sulfide Precipitation and Gravity Settling,
- Vacuum Filtration,
- Flow Equalization,
- Holding Tank - Recycle,
- Multimedia Filtration,
- Membrane Filtration,
- Reverse Osmosis,
- Oil Skimming,
- Contract Hauling.

Lime Precipitation and Gravity Settling. Precipitation using lime followed by gravity settling is a fundamental technology for metals removal. In practice, either quicklime (CaO) or hydrated lime can be used to precipitate toxic and other metals. Hydrated lime is more economical for low lime requirements since the use of slakers, which are necesary for quicklime usage, are practical only for large-volume applications of lime.

Lime is used to adjust the pH of the influent waste stream to a value of approximately 9, at which optimum precipitation of the metals is assumed to occur (see Section VII, page 303), and to react with the metals to form metal hydroxides. The lime dosage is calculated as a theoretical stoichiometric requirement based on the influent metals concentrations and pH. The actual lime dosage requirement is obtained by assuming an excess of 10 percent of the theoretical lime dosage. The effluent concentrations are based on the lime precipitation treatment effectiveness values in Table VII-21 (page 418).

The costs of lime precipitation and gravity settling were based on one of three operation modes, depending on the influent flowrate: continuous, normal batch, and "low flow" batch. The use of a particular mode for costing purposes was determined on a least (total annualized) cost basis for a given flowrate. The economic breakpoint between continuous and normal batch was estimated to be 10,600 liters/hour. Below 2,000 liters/hour, it was found that the "low flow" batch system was most economical.

For a continuous operation, the following equipment were included in the determination of capital and annual costs:

- Lime feed system (continuous)
  1. Storage units (sized for 30-day storage)
  2. Slurry mix tank (5 minute retention time)
  3. Feed pumps
  4. Instrumentation (pH control)

- Polymer feed system
  1. Storage hopper
  2. Chemical mix tank
  3. Chemical metering pump

- pH adjustment system
  1. Rapid mix tank, fiberglass (5 minute retention time)
  2. Agitator (velocity gradient is 300/second)
  3. Control system

- Gravity settling system
  1. Clarifier, circular, steel (overflow rate is 0.347 gpm/sq. ft., underflow solids is 3 percent)
  2. Sludge pumps (1), (to transfer flow to and from clarifier)

Ten percent of the clarifier underflow stream is recycled to the pH adjustment tank to serve as seed material for the incoming waste stream.

The direct capital costs of the lime and polymer feed were based on the respective chemical feed rates (dry lb/hour), which are dependent on the influent waste stream characteristics. The flexibility of this feature (i.e., costs are independent of other module components) was previously noted in the description of the cost estimation model. The remaining equipment costs (e.g., for tanks, agitators, pumps) were developed as a function of the influent flowrate (either directly or indirectly, when coupled with the design assumptions). A cost curve is presented in Figure VIII-16 (page 524) for capital costs of the continuous system.

Direct annual costs for the continuous system include operating and maintenance labor for the feed systems and the clarifier, the cost of lime and polymer, maintenance materials and energy costs required to run the agitators and pumps. A cost curve is presented in Figure VIII-16 (page 524) for annual costs of the countinuous systems.

The normal batch treatment system (used for flows greater than 2,000 liters/hour and less than 10,600 liters/hour) consists of the following equipment:

- Lime feed system (batch)
  1. Slurry tank (5 minute retention time)
  2. Agitator
  3. Feed pump

- Polymer feed system
  1. Chemical mix tank
  2. Agitator
  3. Chemical metering pump

- pH adjustment system
  1. Reaction tanks (2), (8 hour retention time each)
  2. Agitators (2), (velocity gradient is 300/second)
  3. Sludge pump (1), (to transfer sludge to dewatering)
  4. pH control system

The reaction tanks used in pH adjustment are sized to hold the wastewater volume accumulated for one batch period (assumed to be 8 hours). The tanks are arranged in a parallel setup so that treatment occurs in one tank while wastewater is accumulating in the other tank. A separate gravity settler is not necessary since settling will occur in the reaction tank after precipitation has taken place. The settled sludge is then pumped to the dewatering stage.

If additional tank capacity is required in the pH adjustment system in excess of 25,000 gallons (largest single fiberglass tank capacity for which cost data were compiled), additional tanks are added in pairs. Costs for a sludge pump and agitator are estimates for each tank. A cost curve is presented in Figure VIII-16 (page 524) for capital costs of the normal batch system.

The cost of operating labor is the major component of the direct annual costs for the normal batch system. For operation of the batch lime feed system, labor requirements range from 15 to 60 minutes per batch, depending on the lime feed rate (5 to 1,000 pounds/batch). This labor is associated with the manual addition of lime (stored in 50 pound bags). For pH adjustment, required labor is assumed to be one hour per batch (for pH control, sampling, valve operation, etc.). Both the pH adjustment tank and the lime feed system are assumed to require 52 hours per year (one hour/week) of maintenance labor. Labor requirements for the polymer feed system are approximately one hour/day, which accounts for manual addition of dry polymer and maintenance associated with the chemical feed pump and agitator.

Direct annual costs also include the cost of chemicals (lime, polymer) and energy required for the pumps and agitators. The costs of lime and polymer used in the model are $47.30/kkg of lime ($43/ton) and $4.96/kg of polymer ($2.25/lb), based on rates obtained from the Chemical Weekly Reporter (lime) and quotations from vendors (polymer). A cost curve is presented in Figure VIII-16 (page 524) for annual costs of the normal batch system.

For small influent flowrates (less than 2,000 liters/hour) it is more economical on a total annualized cost basis to select the "low flow" batch treatment system. The lower flowrates allow an assumption of five days for the batch duration, or holdup, as opposed to eight hours for the normal batch system. However, whenever the total batch volume (based on a five day holdup) exceeds 25,000 gallons, the maximum single batch tank capacity, the holdup is decreased accordingly to maintain the batch volume under this level. Capital and annual costs for the low flow system are based on the following equipment:

- pH adjustment system
  1. Rapid mix/holdup tank (5 days or less retention time)
  2. Agitator
  3. Transfer pump

Only one tank is required for both holdup and treatment because treatment is assumed to be accomplished during non-operating hours (since the holdup time is much greater than the time required for treatment). Costs for a lime feed system are not estimated since lime addition at low application rates can be assumed to be done manually by the operator. A common pump is used for transfer of both the supernatant and sludge through an appropriate valving arrangement. Addition of polymer was assumed to be unnecessary due to the extended settling time available. A cost curve is presented in Figure VIII-16 (page 524), for capital costs of the "low flow" batch system.

As in the normal batch case, annual costs are comprised mainly of labor costs for the low flow batch system. Labor requirements are constant at 1.5 hours per batch for operation (e.g., pH control, sampling, etc.) and 52 hours per year (one hour per week) for maintenance. Labor is also required for the manual addition of lime directly to the batch tank, ranging from 0.25 to 1.5 hours per batch depending on the lime requirement (1 to 500 pounds per batch). Annual costs also include energy costs associated with the pump and agitator. A cost curve is presented in Figure VIII-16 (page 524), for annual costs of the "low flow" batch system.

Sulfide Precipitation and Gravity Settling. Precipitation using sulfide precipitants followed by gravity settling is a technology similar to lime precipitation. In general, sulfide precipitation removes more metals from wastewater than lime precipitation because metal sulfides are less soluble than metal hydroxides.

Sulfide precipitants can be either soluble sulfides (such as sodium sulfide, or sodium bisulfide) or insoluble sulfides (such as ferrous sulfide). Soluble sulfides generate less sludge than insoluble sulfides, are less expensive, and are more commonly used in industry. The sulfide precipitation module is based on the use of sodium sulfide.

The sulfide precipitation system consists of a pH adjustment step with lime followed by a sulfide precipitation step. Lime is used to adjust the pH of the influent waste stream to a value of approximately 9, at which optimum precipitation of the metals is assumed to occur, and to react with the metals to form metal hydroxides. The lime dosage is calculated as a theoretical stoichiometric requirement based on the influent metals concentrations, lime precipitation treatment effectiveness concentration, and pH. The actual lime dosage requirement is obtained by assuming an excess of 10 percent of the theoretical lime dosage. The treatment effectiveness concentrations are based on the lime precipitation treatment effectiveness values in Table VII-21 (page 418).

After pH adjustment, sodium sulfide is added to the wastewater. The sodium sulfide reacts with the metal hydroxides and forms metal sulfides. The metal sulfides are less soluble than the metal hydroxides. Thus, a larger portion of the metals precipitate (compared to lime precipitation) and metals removal is enhanced. The sodium sulfide concentration is calculated as the theoretical stoichiometric requirement based on the influent metals concentration. The actual sodium sulfide dosage is obtained by assuming an excess of 25 percent of the theoretical sodium sulfide dosage. Effluent concentrations are based on treatment effectiveness values for sulfide precipitation.

As with lime precipitation costs, the costs for pH adjustment with lime, sulfide precipitation, and gravity settling are based on one of three operation modes, depending on the influent flowrate: continuous, normal batch, and "low flow" batch. The use of a particular mode for costing purposes was determined on a least (total annualized) cost basis for a given flowrate. The economic breakpoint between continuous and normal batch is assumed to be 10,600 liters/hour. Below 2,000 liters/hour, it is assumed that the "low flow" batch system is most economical.

For a continuous operation, the following equipment were included in the determination of capital and annual costs:

- Lime feed system (continuous)
  1. Storage units (sized for 30-day storage)
  2. Slurry mix tank (5 minute retention time)
  3. Feed pumps
  4. Instrumentation (pH control)

- Sodium sulfide feed system (continuous)
  1. Storage units (sized for 30-day storage)
  2. Mix tank (5 minute retention time)
  3. Feed pumps
  4. Hood for ventilation

- Polymer feed system
  1. Storage hopper
  2. Chemical mix tank
  3. Chemical metering pump

- pH adjustment system
  1. Rapid mix tank, fiberglass
  2. Agitator (velocity gradient is 300/second)
  3. Control system

- Sulfide precipitation system
  1. Rapid mix tank, fiberglass
  2. Agitator (velocity gradient is 300/second)
  3. Hood for ventilation

- Flocculation system
  1. Slow mix tank, fiberglass
  2. Agitator (velocity gradient is 100/second)
  3. 2.0 mg/l polymer dosage

- Gravity settling system
  1. Clarifier, circular, steel (overflow rate is 0.347 gpm/sq. ft., underflow solids is 3 percent)
  2. Sludge pumps (1), (to transfer flow to and from clarifier)

The percent of the clarifier underflow stream is recycled to the pH adjustment tank to serve as seed material for the incoming waste stream.

An aeration system (tank and spargers) for removing excess hydrogen sulfide is also included in the costs.

The direct capital costs of the lime, sodium sulfide, and polymer feed systems were based on the respective chemical feed rates (dry lb/hr), which are dependent on the influent waste stream characteristics. A cost curve is presented in Figure VIII-17, (page 525) for capital costs of continuous system.

Direct annual costs for the continuous system include operating and maintenance labor for the feed systems and the clarifier, the cost of lime, sodium sulfide, and polymer, maintenance materials and energy costs required to run the agitators and pumps. A cost curve is presented in Figure VIII-17 (page 525) for annual costs of the continuous system.

The normal batch treatment system (used for 2,000 liters/hour < flow <10,600 liters/hour) consists of the following equipment:

- Lime feed system (batch)
  1. Slurry tank (5 minute retention time)
  2. Agitator
  3. Feed pump

- Polymer feed system
  1. Chemical mix tank
  2. Agitator
  3. Chemical metering pump

- Sodium sulfide feed system
  1. Mix tank (5 minute retention time)
  2. Agitator
  3. Feed pump
  4. Hood for ventilation

- pH adjustment and sulfide precipitation system
  1. Reaction tanks (8 hour retention time each)
  2. Agitators (Velocity gradient is 300/second)
  3. Sludge pump (1), (to transfer sludge to dewatering)
  4. pH control system
  5. Hood for ventilation

The batch sulfide precipitation system is similar to the batch lime precipitation system. An aeration system (tank and air spargers) for removing excess hydrogen sulfide is included. As with the continuous sulfide precipitation system, the sodium sulfide feed system is ventilated. A cost curve is presented in

Figure VIII-17 (page 525) for capital costs of the normal batch system.

Direct annual costs for batch sulfide precipitation include operating labor costs, the cost of chemicals (lime and sodium sulfide) and energy required for the pumps and agitators. Lime costs are discussed in the lime precipitation section. A cost curve is presented in Figure VIII-17 (page 525) for annual costs of the normal batch system.

The cost used by the model for sodium sulfide is $517/kkg of sodium sulfide ($470/ton). This cost is based on rates from the Chemical Marketing Reporter.

As discussed in the lime precipitation section, for small influent flowrates (less than 2,000 liters/hour) it is more economical on a total annualized cost basis to select the "low flow" batch treatment system. The lower flowrates allow an assumption of five days for the batch duration, or holdup, as opposed to eight hours for the normal batch system. However, whenever the total batch volume (based on a five day holdup) exceeds 25,000 gallons, the maximum single batch tank capacity, the holdup is decreased accordingly to maintain the batch volume under this level. Capital and annual costs for the low flow system are based on the following equipment:

pH adjustment and sulfide precipitation system

1. Rapid mix/holdup tank (5 days or less retention time)
2. Agitator
3. Transfer pump
4. Aeration system (tank and air spargers)
5. Hood for ventilation

Only one tank is required for both holdup and treatment because treatment is assumed to be accomplished during non-operating hours (since the holdup time is much greater than the time required for treatment). Lime and sodium sulfide feed systems are not costed since lime and sodium sulfide addition at low application rates can be assumed to be done manually by the operator. A common pump is used for transfer of both the supernatant and sludge through an appropriate valving arrangement. Addition of polymer was assumed to be unnecessary due to the extending settling time available. A cost curve is presented in Figure VIII-17 (page 525) for capital costs of the "low flow" batch system.

As in the normal batch case, annual costs are comprised mainly of labor costs for the low flow batch system. Labor requirements are constant at 1 hour per batch for operation (e.g., pH control, sampling, etc.) and 52 hours per year (one hour per week) for maintenance. Labor is also required for the manual addition of lime and sodium sulfide directly to the batch tank. A cost curve is presented in Figure VIII-17 (page 525) for annual costs of the "low flow" batch system.

Vacuum Filtration. The underflow from the clarifier is routed to a rotary precoat vacuum filter, which dewaters the hydroxide sludge (it may also include calcium sulfate and fluoride) to a cake of 20 percent dry solids. The dewatered sludge is disposed of by contract hauling and the filtrate is recycled to the rapid mix tank as seed material for sludge formation.

The capacity of the vacuum filter, expressed as square feet of filtration area, is based on a yield value of 14.6 kg of dry solids/hr per square meter of filter area (3 lb/hr/ft^2), with a solids capture of 95 percent. It was assumed that the filter was operated 8 hours/day.

Cost data were compiled for vacuum filters ranging from 0.9 to 69.7 m^2(9.7 to 750 ft^2) in filter surface area. Based on a total annualized cost comparison, it was assumed that it was more economical to directly contract haul clarifier underflow streams which were less than 42 l/hr (0.185 gpm), rather than dewater by vacuum filtration before hauling.

The capital costs for the vacuum filtration include the following:

- Vacuum filter with precoat but no sludge conditioning,
- Housing, and
- Influent transfer pump.

Operating labor cost is the major component of annual costs, which also include maintenance and energy costs. Cost curves for capital and annual costs are presented in Figure VIII-18 (page 526) for vacuum filtration.

Flow Equalization. Flow equalization is accomplished through steel equalization tanks which are sized based on a retention time of eight hours or 16 hours and an excess capacity factor of 1.2. Cost data were available for steel equalization tanks up to a capacity of 500,000 gallons; multiple units were required for volumes greater than 500,000 gallons. The tanks are fitted with agitators with a horsepower requirement of 0.006 kw/1,000 liters

(0.03 hp/1,000 gallons) of capacity to prevent sedimentation. An influent transfer pump is also included in the equalization system. Cost curves for capital and annual costs are presented in Figure VIII-19 (page 527) for equalization at 8 hours and 16 hours retention time, respectively.

Holding Tanks Recycle. A holding tank may be used to recycle water back to a process or for miscellaneous purposes, e.g., hose washdown for plant equipment. Holding tanks are usually implemented when the recycled water need not be cooled. The equipment used to determine capital costs are a fiberglass tank, pump, and recycle piping. Annual costs are only associated with the pump. The capital cost of a fiberglass tank is estimated on the basis of required tank volume. Required tank volume is calculated on the basis of influent flowrate, 20 percent excess capacity, and four hour retention time.

When chemical precipitation is operated in a batch mode (less than 10,600 l/hr), it is assumed that water may be recycled out of the tank used to operate chemical precipitation. Therefore, since a separate holding tank is not required, only a pump and recycle piping are contributors to recycle costs.

Cost curves for capital and annual cost are presented in Figure VIII-20 (page 528) for flowrates less than 2,000 l/hr and greater than 10,600 l/hr respectively. In the lead subcategory under BAT (PSES) water is recycled back to hose washdown after the water is treated by chemical precipitation and settling.

Multimedia Filtration. Multimedia filtration is used as a wastewater treatment polishing device to remove suspended solids not removed in previous treatment processes. The filter beds consist of graded layers of gravel, coarse anthracite coal, and fine sand. The equipment used to determine capital and annual costs are as follows:

- Influent storage tank sized for one backwash volume;
- Gravity flow, vertical steel cylindrical filters with media (anthracite, sand, and garnet);
- Backwash tank sized for one backwash volume;
- Backwash pump to provide necessary flow and head for backwash operations;
- Influent transfer pump; and
- Piping, valves, and a control system.

The hydraulic loading rate is 7,335 lph/m^2 (180 gph/ft^2) and the backwash loading rate is 29,340 lph/m^2 (720 gph/ft^2). The filter is backwashed once per 24 hours for 10 minutes. The backwash volume is provided from the stored filtrate.

Effluent pollutant concentrations are based on treatability of pollutants by filtration technology presented in Section VII.

Cost curves for capital and annual costs are presented in Figure VIII-21 (page 529) for multimedia filtration.

Membrane Filtration. Membrane filtration is used as a wastewater treatment polishing device for suspended solids not removed in previous treatment processes. Cartridge-type filters are used instead of multimedia filters to treat small flows (less than 1,150 liters/hour) since they are more economical compared to multimedia filters (based on a least total annualized cost comparison) at these flows. It was assumed that the effluent quality achieved by these filters was at least the level attained by multimedia filters. The equipment used to determine capital and annual costs for membrane filtration are as follows:

- Influent holding tank sized for eight hours retention

- Pump

- Prefilter
  1. Prefilter cartridges
  2. Prefilter housings

- Membrane filter
  1. Membrane filter cartridges
  2. Housing

The majority of annual cost is attributable to replacement of the spent prefilter and membrane filter cartridges. The maximum loading for the prefilter and membrane filter cartridges was assumed to be 0.225 kg per 10 inch length of cartridge. The annual energy and maintenance costs associated with the pump are also included in the total annual costs. Cost curves for capital and annual costs are presented in Figure VIII-21 (page 529) for membrane filtration.

Reverse Osmosis. Reverse osmosis concentrates the 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.

Data from several manufacturers of reverse osmosis equipment were used to determine capital and annual costs. The following equipment were used in the determination of capital and annual costs:

- pH adjustment tank (15 minute retention)
- Cartridge prefilter
  1. Cartridges
  2. Housing
- Two influent transfer pumps
- Permeate storage tank (one hour retention)
- Brine storage tank (one hour retention)
- Reverse osmosis module
  1. Sulfuric acid feed system
  2. Inhibitor feed system
  3. Conductivity monitor
  4. Membrane cleaning system
  5. Reverse osmosis membranes and housing

Direct annual costs for reverse osmosis include operating and maintenance labor for the feed systems, the cost for sulfuric acid and inhibitor, prefilter cartridge replacement, reverse osmosis module cartridge replacement, and maintenance materials and energy costs required for the pumps and air agitation system. Cost curves for capital and annual costs are presented in Figure VIII-22 (page 530) for reverse osmosis.

Oil Skimming. Oil skimming costs apply to the separation of oil-water mixtures using a coalescent plate-type separator (which is essentially an enhanced API-type oil-water separator). Although the required separator capacity is dependent on many factors, the sizing was based primarily on the influent wastewater flow rate, with the following design values assumed for the remaining parameters of importance:

Parameter	Nominal Design Value
Specific gravity of oil	0.85
Operating temperature (°F)	68
Influent oil concentration (mg/l)	30,000

Extreme operating conditions, such as influent oil concentrations greater than 30,000 mg/l, or temperatures much lower than 68 °F were accounted for in the sizing of the separator.

The capital and annual costs of oil skimming included the following equipment:

- Coalescent plate separator with automatic shutoff valve and level sensor

- Oily waste storage tanks (2-week retention time)
- Oily waste discharge pump
- Effluent discharge pump

Influent flow rates up to 159,100 l/hr (700 gpm) are costed for a single unit; flows greater than 700 gpm require multiple units.

The direct annual costs for oil skimming include the cost of operating and maintenance labor and replacement parts. Annual costs for the coalescent separators alone are minimal and involve only periodic clean out and replacement of the coalescent plates. Cost curves for capital and annual costs are presented in Figure VIII-23 (page 531) for oil skimming.

Contract Hauling. Concentrated sludge and waste oils are removed on a contract basis for off-site disposal. The cost of contract hauling depends on the classification of the waste as being either hazardous or nonhazardous. For nonhazardous wastes, a rate of $0.106/liter ($0.40/gallon) was used in determining contract hauling costs. The cost for contract hauling hazardous wastes is determined from the cost equation shown in Table VIII-4 (page 494). This equation was developed from telephone contacts with waste disposal services. The cost of contract hauling is an annual cost; no capital costs are associated with it. Annual cost curves for contract hauling non-hazardous and hazardous wastes are presented in Figure VIII-24 (page 532).

Compliance Cost Estimation

To calculate the compliance cost estimates, the model was run using input data as described previously. The actual costs are stored in a data file, where they are accessed from electronic spreadsheet software to prepare a cost summary for each plant. An example of this summary may be found in Table VIII-11 (page 489).

All options costed are included on one page. Under each option, there are four columns. The run number refers to which run on the computer the costs were derived from. The total capital column includes the capital cost estimate for each piece of necessary treatment equipment. The required capital column reflects the estimates of the actual capital cost to the plant to purchase and install the equipment by accounting for what that plant has already installed. In other words, the treatment equipment the plant already has in-place is reflected in the required capital column.

NORMAL PLANT

In order to estimate costs for new sources, and pollutant removals and nonwater quality aspects for existing sources, a normal plant and a normal discharging plant were developed. The normal plant, an arithmetic average of plants in the subcategory, is a theoretical plant which contains each process element in the subcategory. The production level for each process element is the average process element production in the subcategory. The flow rates for these process elements are calculated by multiplying the process element production times the production normalized flow for the process element at the various options. In addition, the normal plant was assumed to operate 16 hours per day, five days per week, 50 weeks per year.

The normal discharging plant is a theoretical plant which contains each process element at the average production level for plants that discharge wastewater. This plant was developed because plants which discharge wastewater are generally larger than those which are zero dischargers. The normal discharge plant costs are used as the basis for estimating new source costs. Table VIII-12 (page 507) presents the capital and annual costs for both the normal plant and the normal discharging plant.

NONWATER QUALITY ENVIRONMENTAL ASPECTS

The elimination or reduction of one form of pollution may aggravate other environmental problems. For this reason consideration was given to the effect of this regulation on air pollution, solid waste generation, water scarcity, and energy consumption. While it is difficult to balance pollution problems against each other and against energy utilization, the impacts identified below are justified by the benefits associated with compliance with the limitations and standards. The following are the nonwater quality environmental impacts (including energy requirements) associated with the lead subcategory regulation.

Air Pollution

In general, especially for the lime precipitation systems, 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 baghouses, scrubbers or stack gas precipitators as well as proper incinerator operation and maintenance. Implementation of sulfide technology at existing plants is costly because of the additional retrofitting a plant would have to do to create a safe working environment. Due to their high content of volatile heavy metals, sludges from battery manufacturing are not amenable to incineration except in retorts for metals recovery.

Solid Waste

Costs for treatment sludge handling were included in the computer cost program already discussed and are included in the compliance costs. In addition, the cost impact that wastewater treatment will have on the battery manufacturing category in terms of satisfying RCRA hazardous waste disposal criteria was analyzed for lime and settle technology. Battery manufacturing plants generate an estimated total of 18,960 kkg of solid waste per year from manufacturing process operations, and an indeterminate amount of solid waste from wastewater treatment. Wastewater treatment sludges contain toxic metals including cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc.

Under the BPT limitations for the lead subcategory, an estimated 4,817 kkg/yr of solid waste will be generated. Solid waste generation under the BAT limitations and PSES is estimated to be 4,840 kkg/yr and 62,290 kkg/yr respectively. These sludges will necessarily contain additional quantities (and concentrations) of toxic metal pollutants.

The solid wastes that would be generated at lead subcategory battery manufacturing plants by lime and settle treatment technologies are believed to be not hazardous under Section 3001 of RCRA. This judgement is made based on the recommended technology of lime precipitation using an excess of lime. By the addition of a small excess (approximately 10 percent) of lime during treatment, it is believed that wastewater treatment sludges will pass the EP toxicity test. Therefore, wastewater treatment sludge hauling costs for the lead subcategory were calculated assuming the sludge was nonhazardous. Estimated BPT wastewater treatment sludge hauling costs for the lead subcategory are $44,300 per year. Estimated BAT and PSES wastewater treatment sludge hauling costs are $437,870 per year. Process sludges such as pasting sludge can be reprocessed to recover additional lead value. Thus, there is no cost for disposing process sludge.

If lead subcategory wastewater treatment sludges were considered to be hazardous, the costs for wastewater treatment sludge disposal would double. The impact that hazardous waste sludge hauling costs would have on the lead subcategory was evaluated. Sludge hauling costs were doubled for eight plants and the total annual costs for each plant were summed. The total annual costs ($1983) were compared with the proposed costs for Option 4 (proposed costs for Option 4 updated to 1983 dollars) which projected no plant closures. In all cases, the annual costs for existing plants at BPT and BAT option levels were less than the proposed costs for Option 4. Therefore, it can be concluded that even if individual plants must classify their wastewater treatment sludges as hazardous, the cost of hazardous waste disposal would not cause any plant closures.

Consumptive Water Loss

Where evaporative cooling mechanisms are used, water loss may result and contribute to water scarcity problems, a concern primarily in arid and semi-arid regions. This regulation does not require substantial evaporative cooling and recycling which would cause a significant consumptive water loss.

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. It is estimated that the lead subcategory consumed 0.77 billion kilowatt hours of electrical energy in 1982. Table VIII-13 (page 508) shows the total lead subcategory energy requirement and energy cost for each treatment option. As shown by Table VIII-13, none of the treatment options would increase the current electrical energy consumption by more than one percent.

TABLE VIII-1

BATTERY MANUFACTURING COMPLIANCE COSTS
LEAD SUBCATEGORY

Discharge Status	Option BPT (PSES-0)		Option BAT-1 (PSES-1)		Option BAT-2 (PSES-2)	
	Capital	Annual	Capital	Annual	Capital	Annual
Direct	714,843	499,039	818,501	509,777	968,117	580,628
Indirect	7,887,805	4,635,339	7,121,534	4,072,814	8,390,881	4,723,621
Total	8,602,648	5,134,378	7,940,035	4,582,591	9,358,998	5,304,249

Discharge Status	Option BAT-3 (PSES-3)*		Option BAT-4 (PSES-4)*	
	Capital	Annual	Capital	Annual
Direct	989,487	739,521	1,619,406	930,465
Indirect	11,214,186	8,381,238	18,353,268	10,545,270
Total	12,203,673	9,120,759	19,972,674	11,475,735

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*Plant-by-plant costs were not calculated for Options 3 and 4. Option 3 and 4 costs are based on the normal discharging plant.

All costs are in June, 1983 dollars.

TABLE VIII-2

IN-PLANT COST PROCEDURE CHANGES

Process	Item	Proposal	Revised
Slow Formation	Equipment	Buildings, racks and accessories (undefined)	Racks
	Retrofit	0	20% of rack cost
Final Product Rinse	Equipment	Holding tank (2 hours retention)	Holding tank (1 week retention) Piping for segregation (to acid cutting) 2 pumps Photoelectric eye
Countercurrent Rinsing and Sealant Recycle	Equipment	3 rinse tanks (1/2 hour retention/tank) Flow controller 2 pumps 1 holding tank for sealant recycle (2 hours retention)	Countercurrent rinse: 2 rinse tanks (1/2 hour retention/ tank) Air agitation Flow controller 10 feet of piping to connect tanks

TABLE VIII-2 (Continued)

IN-PLANT COST PROCEDURE CHANGES

Process	Item	Proposal	Revised
Countercurrent Rinsing and Sealant Recycle (Continued)			Sealant recycle: 1 holding tank (2 hour retention) 100 feet of piping for segregation 1 pump
	Countercurrent Rinsing Basis	3 stage rinsing	2 stage rinsing and assumes first stage is in place
	Labor for countercurrent rinsing	Labor cost = 0.0143 x battery production (kg/yr) \$6.6/hour-labor rate	$1.323 \times (\text{lead usage (kg/yr)})^{0.6}$ \$21/hr-labor rate 2.5 min. incremental labor per basket of plates Sampling data-baskets/hr, Pb/hr
Paste Water Recycle	Equipment	3 settling tanks (1 hour retention/tank) Piping for segregation	3 settling tanks (1 hour retention/tank)

TABLE VIII-2 (Continued)

IN-PLANT COST PROCEDURE CHANGES

Process	Item	Proposal	Revised
Paste Water Recycle (Continued)			1 holding tank (1 day retention) Piping for segregation 2 pumps
	Annual labor cost		Annual labor cost for periodically cleaning out settling tanks is included
Stream Segregation Costs	Equipment	Piping and trench	Piping, sump and pump
Five New In-Plant Technologies	General	Not included in in-plant costs	Included in in-plant costs
System Parameters for In-Plant Costs	Engineering contingency and contractor's fee	0%	37.5%
	Interest rate	10%	12%
	Equipment life	10 years	10 years

NOTE:

Installation costs are included in revised equipment costs
Revised equipment costs from end-of-pipe treatment equipment costs, literature, and vendor quotes
System parameters (e.g., interest rate) are consistent with end-of-pipe treatment module parameters

TABLE VIII-3

COST DIFFERENCE COMPARISON - PROMULGATED VS. PROPOSED

	ΔBPT (%)		ΔBAT-1 (%)		ΔBAT-2 (%)	
Plant	Capital	Annual	Capital	Annual	Capital	Annual
146	-38	80	-80	-32	-78	-35
331	-10	122	-46	-4	-41	-15
382	---	---	---	---	---	---
446	-38	109	-88	-9	-89	-12
450	---	---	---	---	---	---
462	-68	101	-71	-12	-72	-12
513	-40	36	-85	-41	-82	-37
553	-57	59	-78	-45	-73	-41
815	-84	-42	-85	-45	-82	-52
943	71	135	-45	-46	-55	-46
Mean(%)	-33	75	-72	-30	-72	-31

NOTES:

% = [(Promulgation Cost - Proposal Cost)/(Proposal Cost)] x 100

n = 8

TABLE VIII-4

COST EQUATIONS FOR RECOMMENDED TREATMENT AND CONTROL TECHNOLOGIES

Equipment	Equation	Range of Validity
Agitator, C-clamp	$C = 839.1 + 587.5\ (HP)$ $A = 0.746\ (HPY)(HP)(0.0483) + 0.05\ (C)$	$0.25 < HP \leq 0.33$
Agitator, Top Entry	$C = 1{,}585.55 + 125.302\ (HP) - 3.27437\ (HP)^2$ $A = 0.746\ (HPY)(HP)\ (0.0483) + 0.05\ (C)$	$0.33 < HP < 5.0$
Clarifier, Concrete	$C = 78{,}400 + 32.65\ (S) - 7.5357 \times 10^{-4}\ (S)^2$ $A = \exp[8.22809 - 0.224781\ (\ln S) + 0.0563252\ (\ln S)^2]$	$500 < S < 12{,}000$
Clarifier, Steel	$C = 41{,}197.1 + 72.0979(S) + 0.0106542(S)^2$ $A = \exp[8.22809 - 0.224781\ (\ln S) + 0.0563252\ (\ln S)^2]$	$300 < S < 2{,}800$
Contract Hauling	$C = 0$ $A = 0.40\ (G)(HPY)$	Non Hazardous
	$C = 0$ $A = \exp[-0.0240857 + 1.02731\ (\ln G) - 0.0196787\ (\ln G)^2](HPY)$	Hazardous
Equalization Tank, Steel	$C = 14{,}759.8 + 0.170817\ (V) - 8.44271 \times 10^{-8}\ (V)^2$	$24{,}000 < V < 500{,}000$
	$C = 3{,}100.44 + 1.19041\ (V) - 1.7288 \times 10^{-5}\ (V)^2$	$1{,}000 < V < 24{,}000$
	$C = \exp[4.73808 - 0.0628537\ (\ln V) + 0.0754345\ (\ln V)^2]$	$V < 1{,}000$
	$A = 0.05\ (C)$	

TABLE VIII-4 (Continued)

COST EQUATIONS FOR RECOMMENDED TREATMENT AND CONTROL TECHNOLOGIES

Equipment	Equation	Range of Validity
Feed System, Caustic	Continuous feed: $C = \exp[9.63461 + 8.36122 \times 10^{-3} (\ln F) + 0.0241809 (\ln F)^2]$	$0.4 < F < 417$
	Batch feed: $C = \exp[7.50026 + 0.199364 (\ln F) + 0.0416602 (\ln F)^2]$	$1.5 < F < 1{,}500$
	Low Flow Batch: $C = 250$	$X \leq 100$
	Annual Costs: Continuous feed: $A = \exp[7.9707 - 4.45846 \times 10^{-3} (\ln F) + 0.0225972 (\ln F)^2] + 0.183 (HPY)(F)$	$0.4 < F < 417$
	Batch feed: $A = (21)[16 + 0.5 (BPY)] + 0.131 (F)(HPY)(HPB)$	$1.5 < F < 1{,}500$
	Low Flow Batch: $A = (21)(0.5) (BPY) + 0.131 (F)(HPY)(HPB)$	$X \leq 100$
Feed System, Manual Lime Addition	$C = 0$ $A = (DPY)[0.074 (B) + 5.25 (NB)]$	$X \leq 2{,}200$
Feed System, Batch Lime	$C = 1{,}697.79 + 19.489 (B) - 0.036824 (B)^2$	$1 < B < 200$
	$C = 16{,}149.2 + 10.2512 (B) - 1.65864 \times 10^{-3} (B)^2$	$B \geq 200$
	$A = (BPY)[5.01989 + 0.0551812 (B) - 1.79331 \times 10^{-5} (B)^2] + 545$	

TABLE VIII-4 (Continued)

COST EQUATIONS FOR RECOMMENDED TREATMENT AND CONTROL TECHNOLOGIES .

Equipment	Equation	Range of Validity
Feed System, Lime (Continuous)	$C = \exp[6.32249 + 1.70246\ (\ln F) - 0.137186\ (\ln F)^2]$ $A = \exp[4.87322 + 1.78557\ (\ln F) + 0.136732\ (\ln F)^2] + (F)(HPY)(LC)$	$10 < F < 1{,}000$
Feed System, Sodium Sulfide	$C = 13{,}953.3 + 117.18\ (F) - 0.069117\ (F)^2$ $A = [0.758002 + 0.140318\ (F) - 8.6493 \times 10^{-8}\ (F)^2](HPY)$	$10 < F < 5{,}350$
Feed System, Polymer	$C = \exp[9.83111 + 0.663271\ (\ln F) + 0.0557039\ (\ln F)^2]$	$0.04 < F < 0.5$
	$C = 13{,}150 + 2515.2\ (F)$	$0.5 \leq F < 12$
	$A = (HPY)[0.42 + F] + 1{,}050$	$F < 0.5$
	$A = \exp[8.60954 + 0.04109\ (\ln F) + 0.0109397\ (\ln F)^2] + 2.25\ (F)(HPY)$	$0.5 \leq F < 12$
Feed System, Sulfuric Acid	$C = \exp[8.1441 + 0.23345\ (\ln F) + 0.0180092\ (\ln F)^2]$ $A = \exp[7.36913 + 0.0133111\ (\ln F) + 0.029219\ (\ln F)^2] + 0.03743\ (F)(HPY)$	$0.01 < F < 3{,}200$
Filter, Multimedia	$C = 10{,}888 + 277.85\ (SA) - 0.154337\ (SA)^2$ $A = \exp[8.20771 + 0.275272\ (\ln SA) + 0.0323124\ (\ln SA)^2]$	$7 < SA < 500$
Filter, Membrane	$C = 290.48 + 31.441\ (Y) - 0.050717\ (Y)^2$ $A = [8.34253 \times 10^{-3} + 0.173683\ (SR) - 4.1435 \times 10^{-5}\ (SR)^2](HPY)$	$2 < Y < 140$
	$C = -2{,}922.48 + 60.6411\ (Y) - 0.065206\ (Y)^2$ $A = [-0.0152849 + 0.172153\ (SR) - 3.46041 \times 10^{-6}\ (SR)^2](HPY)$	$140 < Y < 336$

TABLE VIII-4 (Continued)

COST EQUATIONS FOR RECOMMENDED TREATMENT AND CONTROL TECHNOLOGIES

Equipment	Equation	Range of Validity
Prefilter, Cartridge	$C = 283.353 + 25.9111\ (Y) - 0.058203\ (Y)^2$ $A = [0.118985 + 0.0803004\ (SR) - 1.66003 \times 10^{-5}\ (SR)^2](HPY)$	$2 < Y < 140$
	$C = -2{,}612.73 + 51.568\ (Y) - 0.059361\ (Y)^2$ $A = [-3.82339 + 0.0937196\ (SR) - 1.7736 \times 10^{-5}\ (SR)^2](HPY)$	$140 < Y < 336$
Oil-Water Separator	$C = 5{,}542.07 + 65.7158\ (Y) - 0.029627\ (Y)^2$ $A = 783.04 + 6.3616\ (Y) - 0.001736\ (Y)^2$	$0 < Y < 700$
Piping, Recycle	$C = \exp[6.55278 + 0.382166\ (\ln D) + 0.133144\ (\ln D)^2]\ (0.01)(L)$ $A = 0$	$D \geq 1$
Pump, Centrifugal	$C = \exp[6.31076 + 0.228887(\ln Y) + 0.0206172\ (\ln Y)^2]$ $A = \exp[6.67588 + 0.031335\ (\ln Y) + 0.062016\ (\ln Y)^2]\ (HPB)$	$3 < Y < 3{,}500$
Pump, Sludge	$C = 2{,}264.31 + 21.0097\ (Y) - 0.0037265\ (Y)^2$ $A = \exp[7.64414 + 0.192172\ (\ln Y) + 0.0202428\ (\ln Y)^2]\ (HPB)$	$5 < Y < 500$
Reverse Osmosis System	$C = \exp[6.82042 + 0.505285\ (\ln X) + 4.77736 \times 10^{-3}\ (\ln X)^2]$ $A = [1.39054 + 3.54401 \times 10^{-4}\ (X) + 1.0307 \times 10^{-10}\ (X)^2](HPY)$	$16 < X < 120{,}000$

TABLE VIII-4 (Continued)

COST EQUATIONS FOR RECOMMENDED TREATMENT AND CONTROL TECHNOLOGIES

Equipment	Equation	Range of Validity
Tank, Batch Reactor	$C = \exp[4.73808 - 0.0628537 (\ln V) + 0.0754345 (\ln V)^2]$	$57 < V < 1,000$
	$A = 1,091 + 21 (BPY)$	$X < 2,200$
	$C = 3,100.44 + 1.19041 (V) - 1.7288 \times 10^{-5}(V)^2$	$1,000 < V < 24,000$
	$A = \exp[8.65018 - 0.0558684 (\ln X) + 0.0145276 (\ln X)^2]$	$2,200 < X < 11,600$
Tank, Concrete	$C = 5,800 + 0.8V$	$24,000 < V < 500,000$
	$A = 0.02 (C)$	
Tank, Large Fiberglass	$C = 3,100.44 + 1.19041 (V) - 1.7288 \times 10^{-5}(V)^2$	$1,000 < V < 24,000$
	$A = 0.02 (C)$	
Tank, Small Fiberglass	$C = \exp[4.73808 - 0.0628537 (\ln V) + 0.0754345 (\ln V)^2]$	$V \leq 1,000$
	$A = 0.02 (C)$	
Tank, Large Steel	$C = 3,128.83 + 2.37281 (V) - 7.10689 \times 10^{-5}(V)^2$	$500 < V < 12,000$
	$C = 14,759.8 + 0.170817 (V) - 8.44271 \times 10^{-8} (V)^2$	$V \geq 25,000$
	$A = 0.02 (C)$	
Tank, Small Steel	$C = 692.824 + 6.16706 (V) - 3.95367 \times 10^{-3}(V)^2$	$100 < V < 500$
	$A = 0.02 (C)$	

TABLE VIII-4 (Continued)

COST EQUATIONS FOR RECOMMENDED TREATMENT AND CONTROL TECHNOLOGIES

Equipment	Equation	Range of Validity
Vacuum Filter	$C = 71{,}083.7 + 442.3\ (SA) - 0.233807\ (SA)^2$ $A = 17{,}471.4 + 677.408\ (SA) - 0.484647\ (SA)^2$	$9.4 < SA < 750$
Vacuum Filter Housing	$C = (45)[308.253 + 0.836592\ (SA)]$ $A = (4.96)[308.253 + 0.836592\ (SA)]$	$9.4 < SA < 750$

A = Direct annual costs (1982 dollars/year)
B = Batch chemical feed rate (pounds/batch)
BPY = Number of batches per year
C = Direct capital, or equipment costs (1982 dollars)
D = Inner diameter of pipe (inches)
F = Chemical feed rate (pounds/hour)
G = Sludge disposal rate (gallons/hour)
HP = Power requirement (horsepower)
HPB = Fraction of time equipment is in operation
HPY = Plant operating hours (hours/year)
L = Length of piping (feet)
LC = Lime cost ($/lb, March 1982)
S = Clarifier surface area (square feet)
SA = Filter surface area (square feet)
SR = Solids removed by filter (grams/hour)
V = Tank capacity (gallons)
X = Wastewater flowrate (liters/hour)
Y = Wastewater flowrate (gallons/minute)

TABLE VIII-5

COMPONENTS OF TOTAL CAPITAL INVESTMENT

Item Number	Item	Cost
1	Bare Module Capital Costs	Direct capital costs from model[a]
2	Electrical & instrumentation	0% of item 1
3	Yard piping	0% of item 2
4	Enclosure	Included in item 1
5	Pumping	Included in item 1
6	Retrofit allowance	Included in item 1
7	Total Module Cost	Item 1 + items 2 through 6
8	Engineering/admin. & legal	10.0% of item 7
9	Construction/yardwork	0% of item 7
10	Monitoring	0% of item 7
11	Total Plant Cost	Item 7 + items 8 through 10
12	Contingency	15% of item 11
13	Contractor's fee	10% of item 11
14	Total Construction Cost	Item 11 + items 12 through 13
15	Interest during construction	0% of item 14
16	Total Depreciable Investment	Item 14 + item 15
17	Land	0% of item 16
18	Working capital	0% of item 16
19	Total Capital Investment	Item 16 + items 17 through 18

---

[a] Direct capital costs include costs of equipment and required accessories, installation, and delivery.

TABLE VIII-6

COMPONENTS OF TOTAL ANNUALIZED COSTS

Item Number	Item	Cost
20	Bare Module Annual Costs	Direct annual costs from model[a]
21	Overhead	0% of item 16[b]
22	Monitoring	See footnote c
23	Insurance	1% of item 16
24	Amortization	CRF x item 16[d]
25	Total Annualized Costs	Item 20 + items 21 through 24

---

[a] Direct annual costs include costs of raw materials, energy, operating labor, maintenance and repair.

[b] Item 16 is the total depreciable investment obtained from Table 1.

[c] See page 463 for an explanation of the determination of monitoring costs.

[d] The capital recovery factor (CRF) was used to account for depreciation and the cost of financing.

TABLE VIII-7

WASTEWATER SAMPLING FREQUENCY

Wastewater Discharge (Liters Per Day)	Sampling Frequency
0 - 37,850	Once per month
37,851 - 189,250	Twice per month
189,251 - 378,500	Once per week
378,501 - 946,250	Twice per week
946,250+	Three times per week

TABLE VIII-8

IN-PLANT COST FREQUENCY SUMMARY

Technology	BPT-PSES 0	BPT-PSES 1
Paste Mixing and Application Area Wash Water Recycle	28	28
Steam Curing	6	6
Humidity Curing Water Recycle	13	13
Slow Formation	8	10
Plate Countercurrent Rinsing	0	34
Sealant Water Recycle	0	5
Formation Area WAPC Water Recycle	25	25
Paste Mixing WAPC Water Neutralization	31	31
Reuse of Battery Rinse Water in Acid Cutting	1	50*
Power Floor Scrubber Water Settling	85	85
Hose Washdown Water Recycle	85	85
Segregation of Nonprocess Water Flows	85	85

*Reuse of battery rinse water in acid cutting was costed for 16 plants to eliminate discharges from formation battery rinsing.

TABLE VIII-9

NONPROCESS WATER DISPOSITION AMONG PLANTS VISITED IN POST-PROPOSAL PERIOD

Stream	Number of Plants With Total Recycle	Number of Plants That Already Segregate	Number of Plants That Discharge Stream To Wastewater Treatment	Number of Plants Which Do Not Have Stream
Deionizer Blowdown* and Water Softener Backflush	-	1	2	-
Assembly Noncontact* Cooling	1 (5)	-	2	-
Leady Oxide Production Cooling	6	-	4	7
Grid Mold Cooling Operations	7	2	3	3
Air Compressor Cooling	1 (5)	-	1	-
Boiler Water[1] Blowdown	-	-	1 (5)	-
Cooling Tower Blowdown	-	2 (5)	-	-
Shower Water	-	11	-	-

*Selected for segregation modeling
[1] Associated with curing operation
( ) Plants visited represents a model for five plants

TABLE VIII-10

COST PROGRAM POLLUTANT PARAMETERS

Parameter	Units
Flowrate	liters/hour
pH	pH units
Temperature	°F
Total Suspended Solids	mg/l
*Acidity (as $CaCO_3$)	mg/l
Aluminum	mg/l
*Ammonia	mg/l
Antimony	mg/l
Arsenic	mg/l
Cadmium	mg/l
**Chromium (trivalent)	mg/l
**Chromium (hexavalent)	mg/l
Cobalt	mg/l
Copper	mg/l
*Cyanide (free)	mg/l
*Cyanide (total)	mg/l
*Fluoride	mg/l
Iron	mg/l
Lead	mg/l
Manganese	mg/l
Nickel	mg/l
Oil and Grease	mg/l
*Phosphorous	mg/l
*Selenium	mg/l
*Silver	mg/l
*Thallium	mg/l
Zinc	mg/l

*Not analyzed for lead subcategory of battery manufacturing

**Assume chromium is in trivalent form for lead subcategory of battery manufacturing

TABLE VIII-11

EXAMPLE PLANT SUMMARY

EQUIPMENT	OPTION BPT RUN	OPTION BPT TOTAL CAPITAL	OPTION BPT REQUIRED CAPITAL	OPTION BPT ANNUAL	OPTION BAT-1 RUN	OPTION BAT-1 TOTAL CAPITAL	OPTION BAT-1 REQUIRED CAPITAL	OPTION BAT-1 ANNUAL	OPTION BAT-2 RUN	OPTION BAT-2 TOTAL CAPITAL	OPTION BAT-2 REQUIRED CAPITAL	OPTION BAT-2 ANNUAL
EQUALIZATION	1	32500	6600	5300	2	20200	6600	3200	2	20200	6600	3200
OIL SKIMMING	1	2600	2600	1300	2	2600	2600	1300	2	2600	2600	1300
CHEM PRECIPITATION	1	24300	0	13300	2	32100	0	16400	2	32100	0	16400
GRAVITY SETTLING	1	67300	0	9600		(4)				(4)		
VACUUM FILTRATION		(5)				(5)				(5)		
MULTIMED FILTRATION									2	18000	18000	7600
CONTRACT HAULING	1	0	0	11300	2	0	0	4200	2	0	0	4200
HOLD TANKS, RECYCLE					2	2300	2300	900	2	2300	2300	900
IN-PLANT COSTS		8600	8600	1600		8600	8600	1600		8600	8600	1600
SUBTOTAL		135300	17800	42400		65800	20100	27600		83800	38100	35200
SYSTEM CAP COSTS		50737	6675			24675	7537			31425	14287	
ENCLOSURE		0	0	0		0	0	0		0	0	0
INSURANCE & TAXES				1860				904				1152
AMORTIZATION				4332				4891				9272
MONITORING				2880				1440				1440
TOTAL		186037	24475	51472		90475	27637	34835		115225	52387	47064
TOTAL (JUNE 1983)		189014	24867	52296		91923	28079	35392		117069	53225	47817

LBS OF BATTERIES/YR: 8,500,000

	BPT	BAT-1	BAT-2
NORMALIZED COST (JUNE 83 $/LB):	.0061524	.0041638	.0056255

FOOTNOTES:

1. All costs are in March,1982 dollars except where indicated.
2. System capital costs are calculated as 37.5% of the total direct capital costs (capital subtotal).
3. Amortization is calculated as 17.7% of the total required capital costs.
4. Chemical precipitation operated in batch mode; gravity settling not costed.
5. Flow to vacuum filter is less than minimum for sizing (42 l/hr). Stream is contract hauled.

1/11/84

TABLE VIII-12

NORMAL PLANT CAPITAL AND ANNUAL COSTS

Normal Plant Costs:

Option	Capital Cost	Annual Cost
BPT (PSES 0)	107,708	67,263
BAT 1 (PSES 1)	91,782	46,159
BAT 2 (PSES 2)	111,760	54,976
BAT 3 (PSES 3)	100,025	64,787
BAT 4 (PSES 4)	149,339	88,316
BDT 5 (PSNS 5)	111,760	54,976

Normal Discharging Plant Costs:

Option	Capital Cost	Annual Cost
BPT (PSES 0)	122,377	75,085
BAT 1 (PSES 1)	98,628	59,529
BAT 2 (PSES 2)	119,443	69,010
BAT 3 (PSES 3)	109,943	82,169
BAT 4 (PSES 4)	179,934	103,385
BDT 5 (PSNS 5)	119,443	69,010

All costs are based on June 1983 dollars.

TABLE VIII-13

ENERGY COSTS AND REQUIREMENTS

Option	Costs $/yr	Energy Requirement kwh/yr	Percent Increase Over Current Energy Consumption
BPT (PSES-0)	263,000	5,360,000 (386,540)	0.70
BAT-1 (PSES-1)	206,000	4,200,000 (302,576)	0.55
BAT-2 (PSES-2)	222,000	4,400,000 (327,184)	0.57
BAT-3 (PSES-3)	222,000	4,400,000 (327,184)	0.57
BAT-4 (PSES-4)	309,000	6,320,000 (454,912)	0.82

( ) - Indicates energy requirement for direct dischargers.

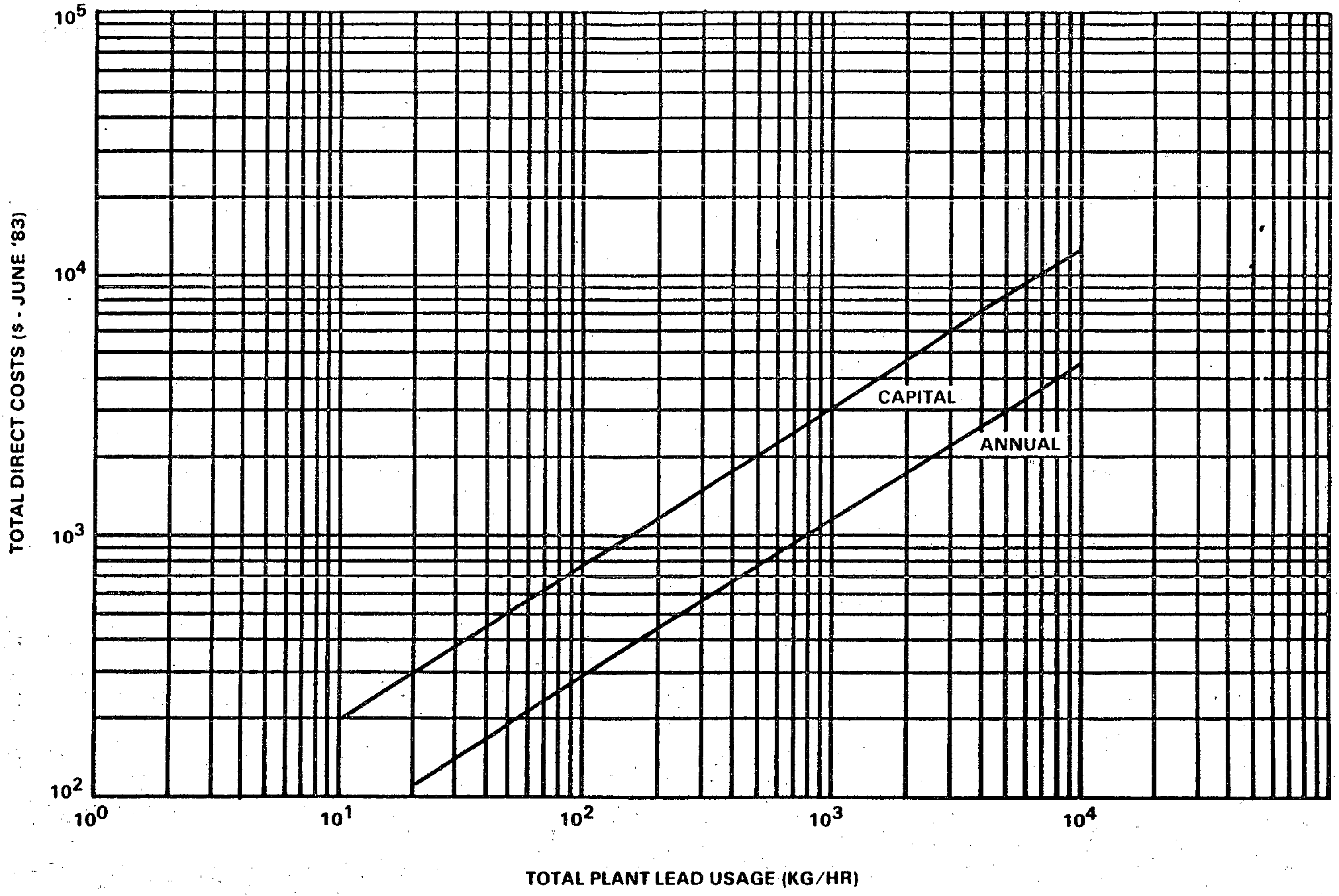


FIGURE VIII-1
COSTS FOR PASTE MIXING AND APPLICATION AREA WASH WATER RECYCLE

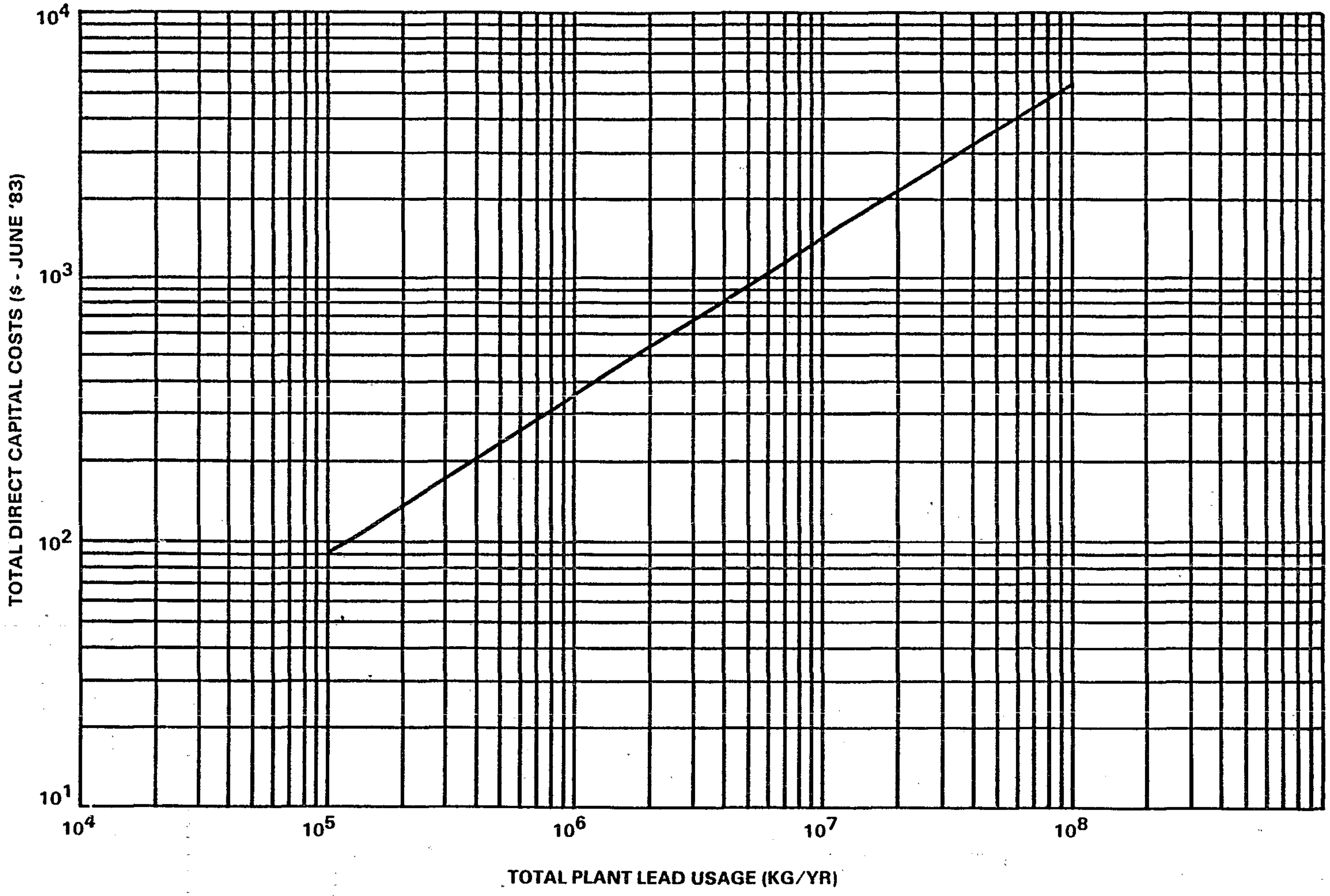


FIGURE VIII-2
COSTS FOR STEAM CURING

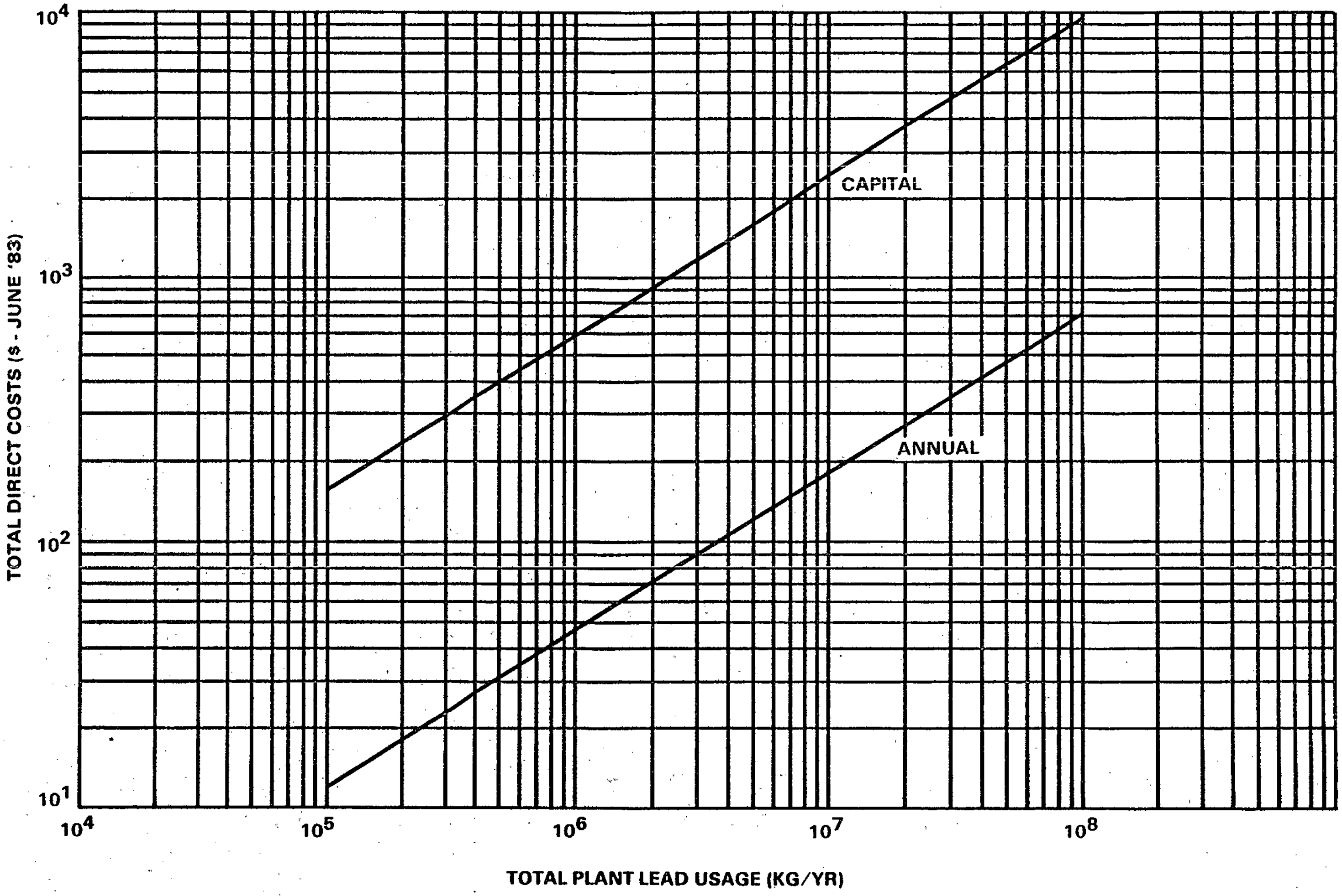


FIGURE VIII-3
COSTS FOR HUMIDITY CURING WATER RECYCLE

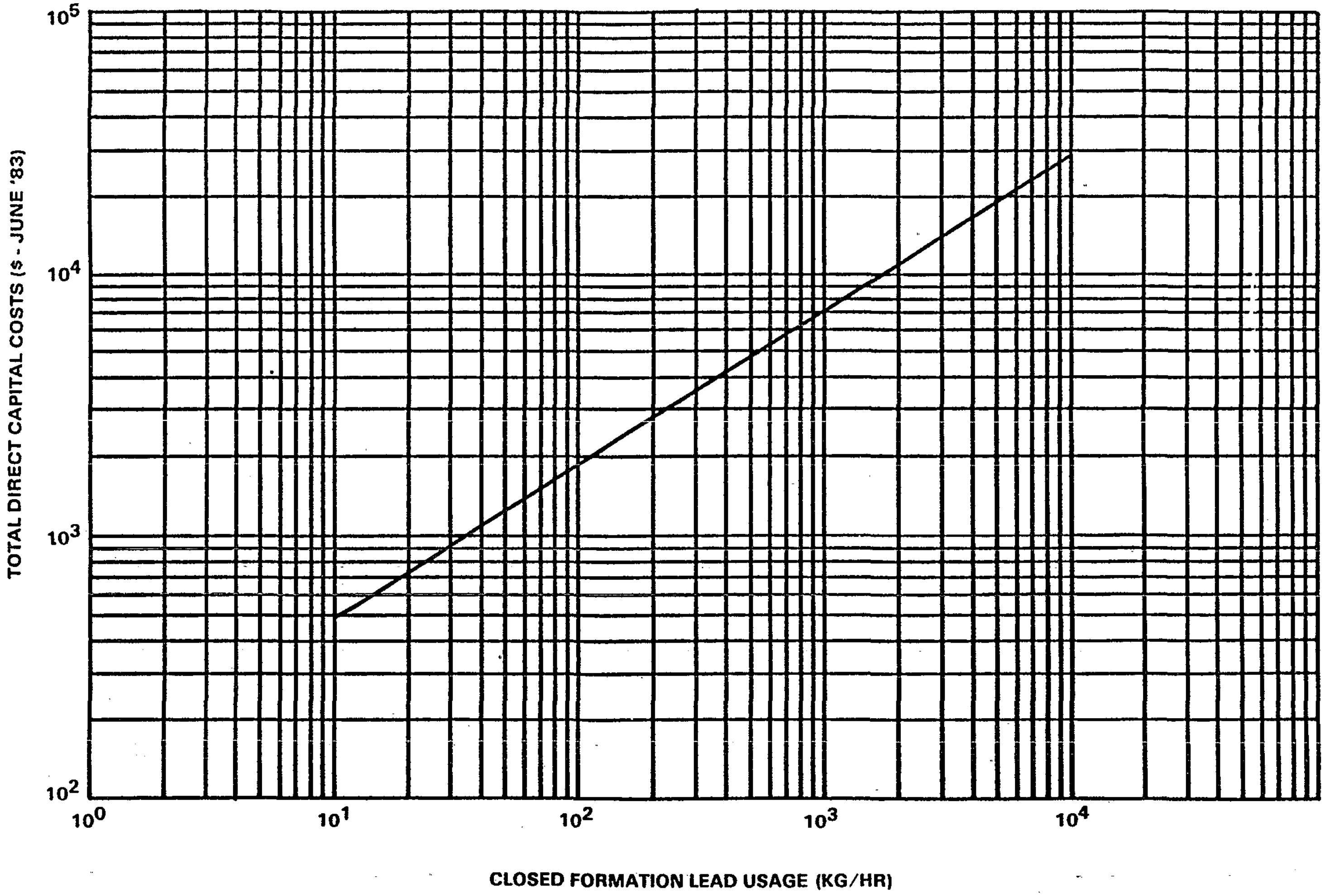


FIGURE VIII-4
COSTS FOR SLOW FORMATION

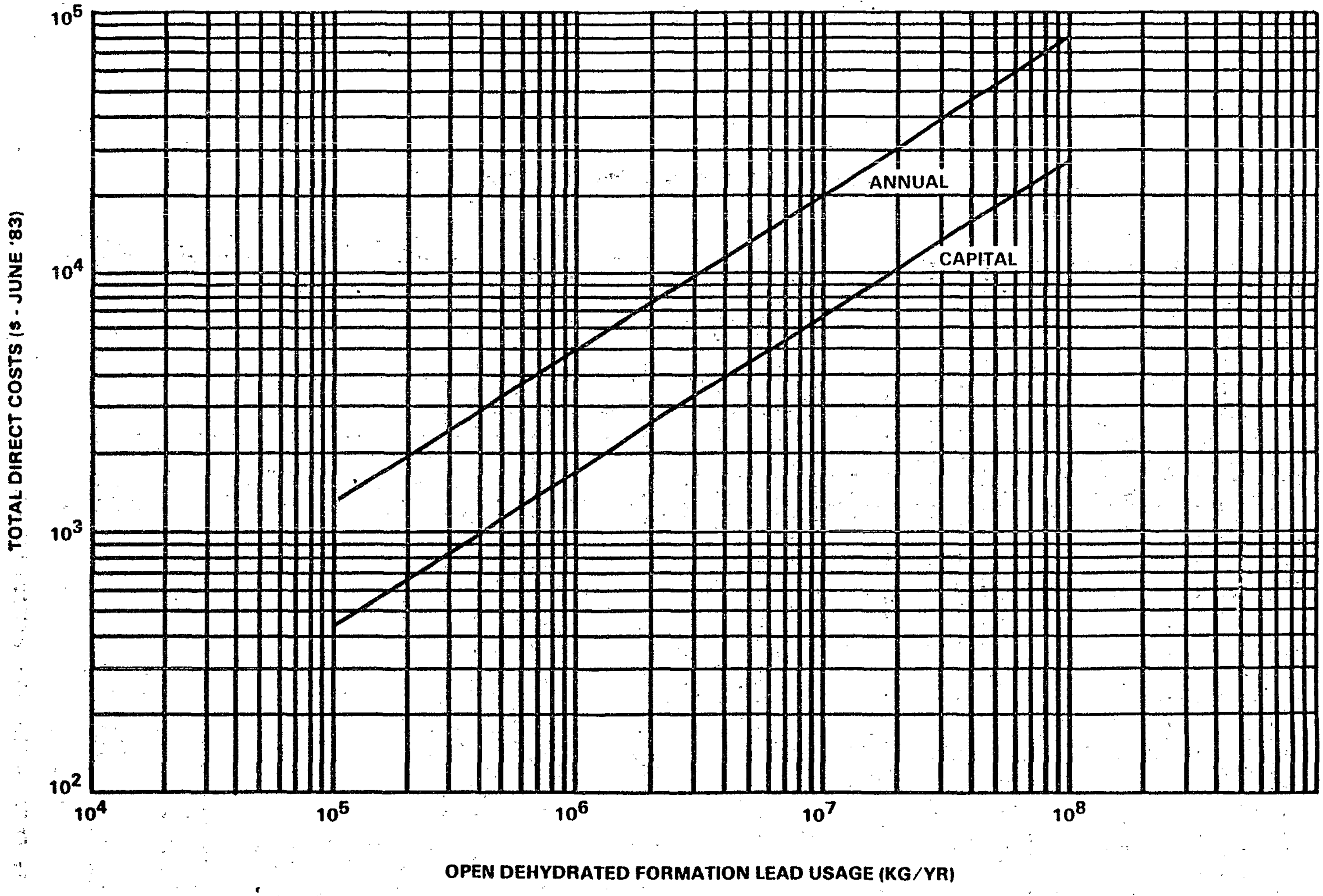


FIGURE VIII-5
COSTS FOR COUNTERCURRENT CASCADE RINSING

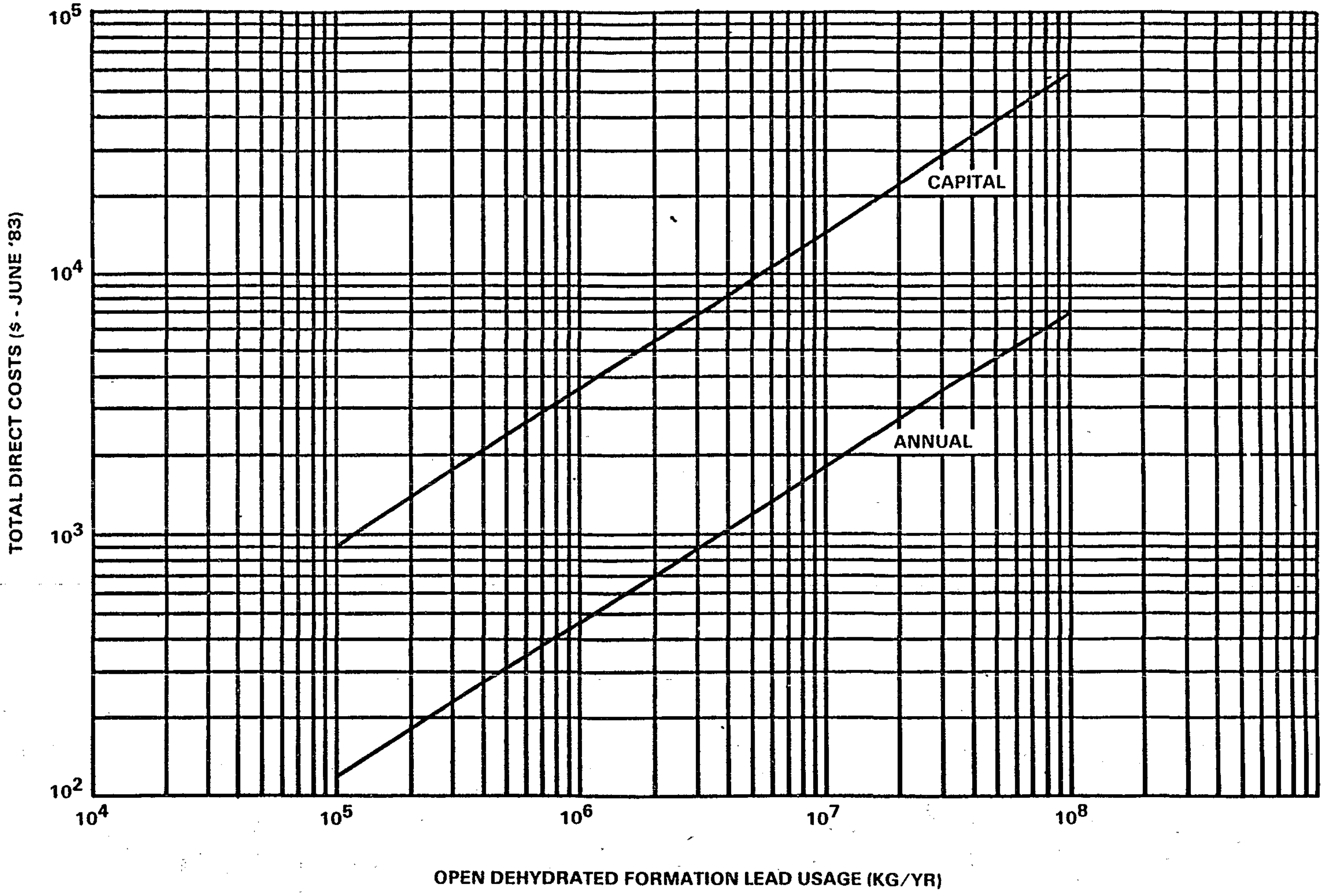


FIGURE VIII-6
COSTS FOR SEALANT WATER RECYCLE

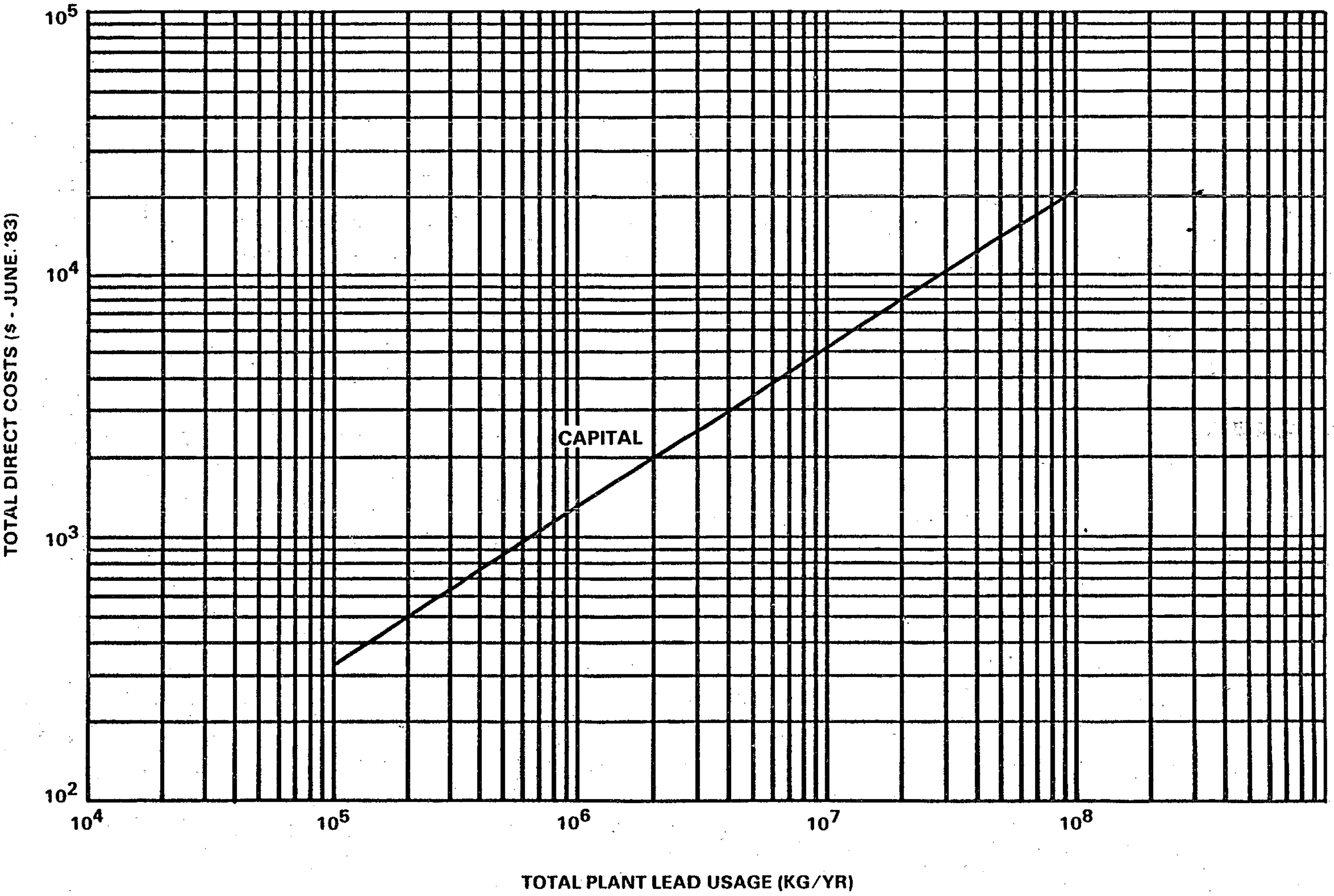


FIGURE VIII-7
CAPITAL COSTS FOR FORMATION AREA WAPC WATER RECYCLE

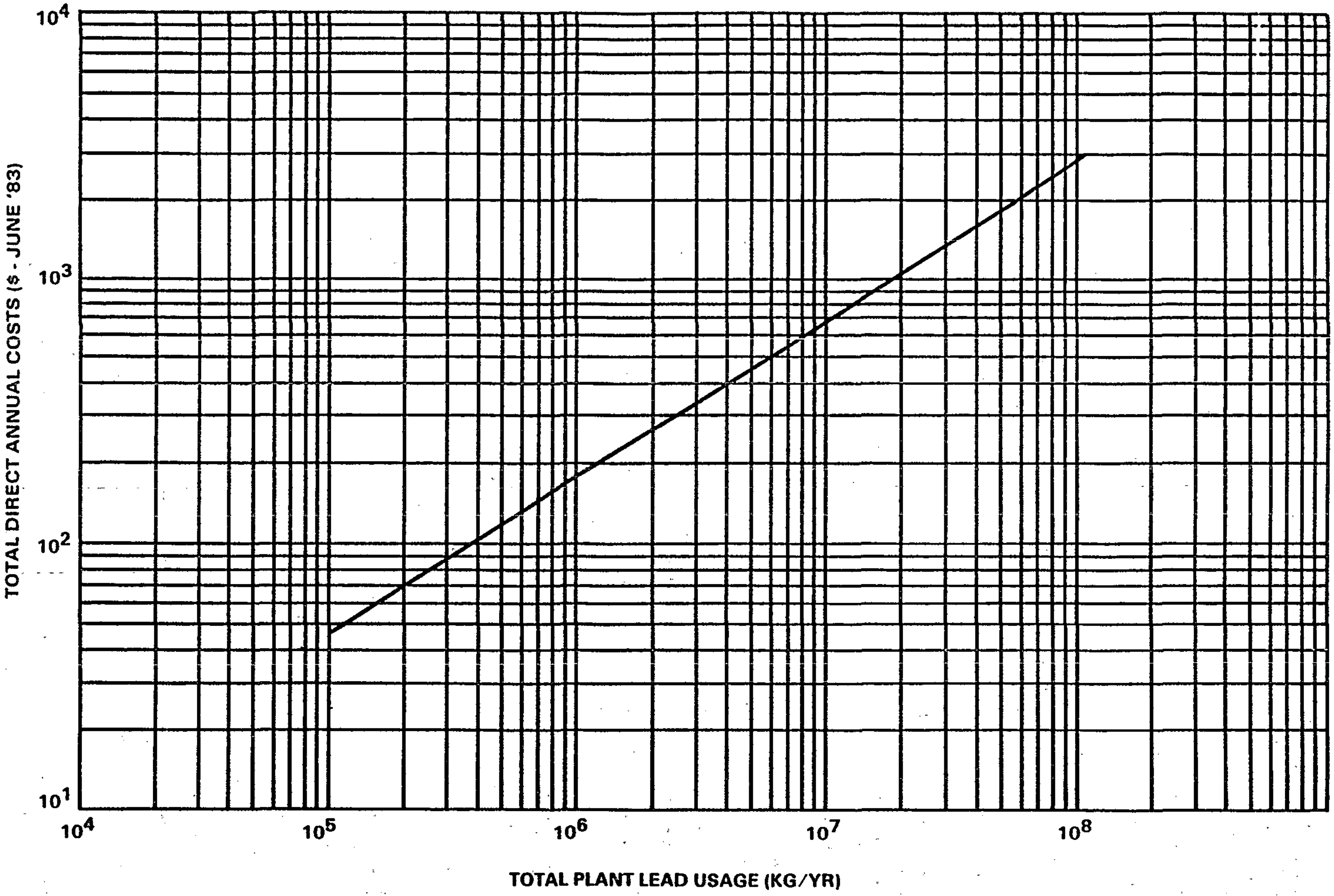


FIGURE VIII-8
ANNUAL COSTS FOR FORMATION AREA WAPC WATER RECYCLE

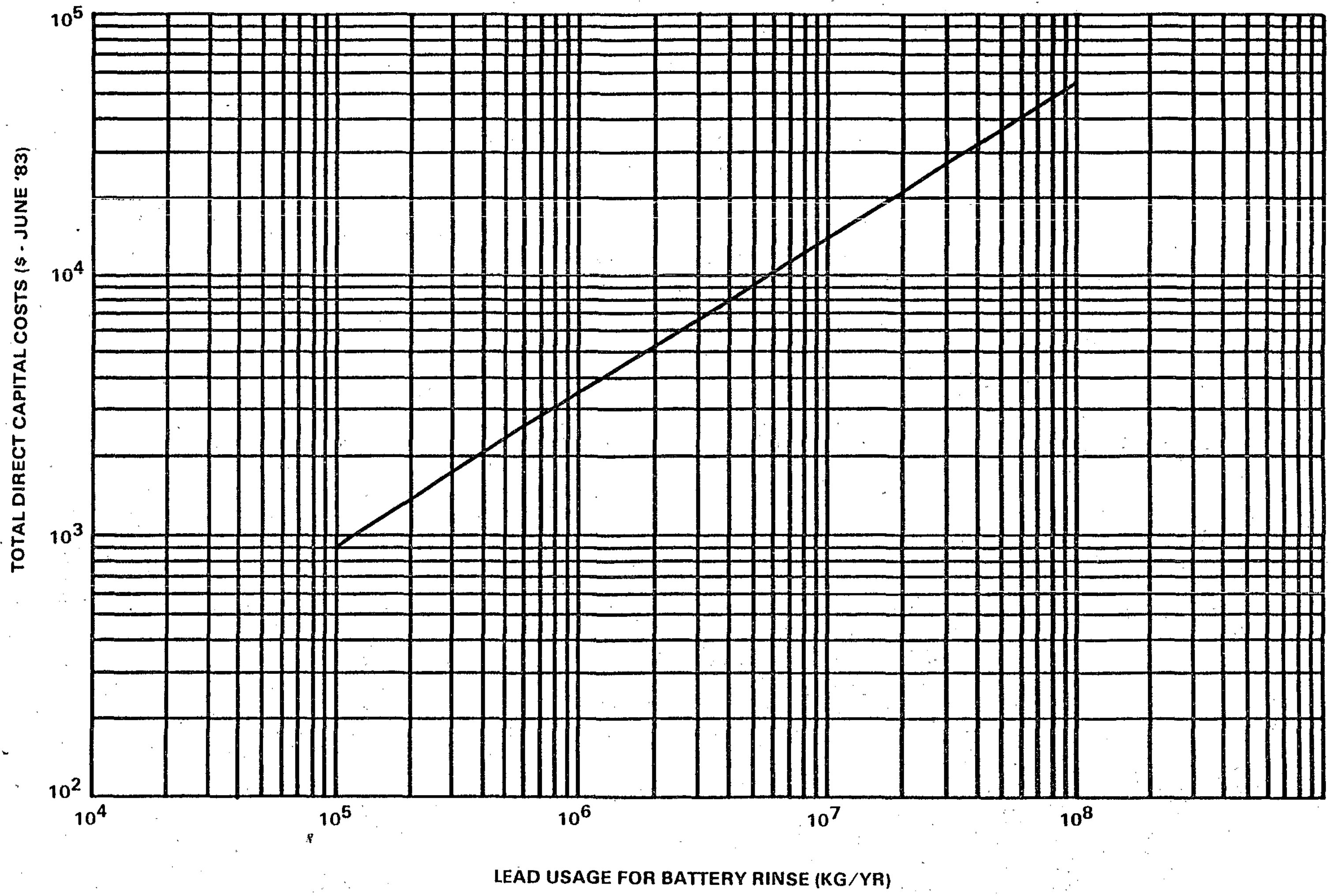


FIGURE VIII-9
CAPITAL COSTS FOR REUSE OF BATTERY RINSE WATER IN ACID CUTTING

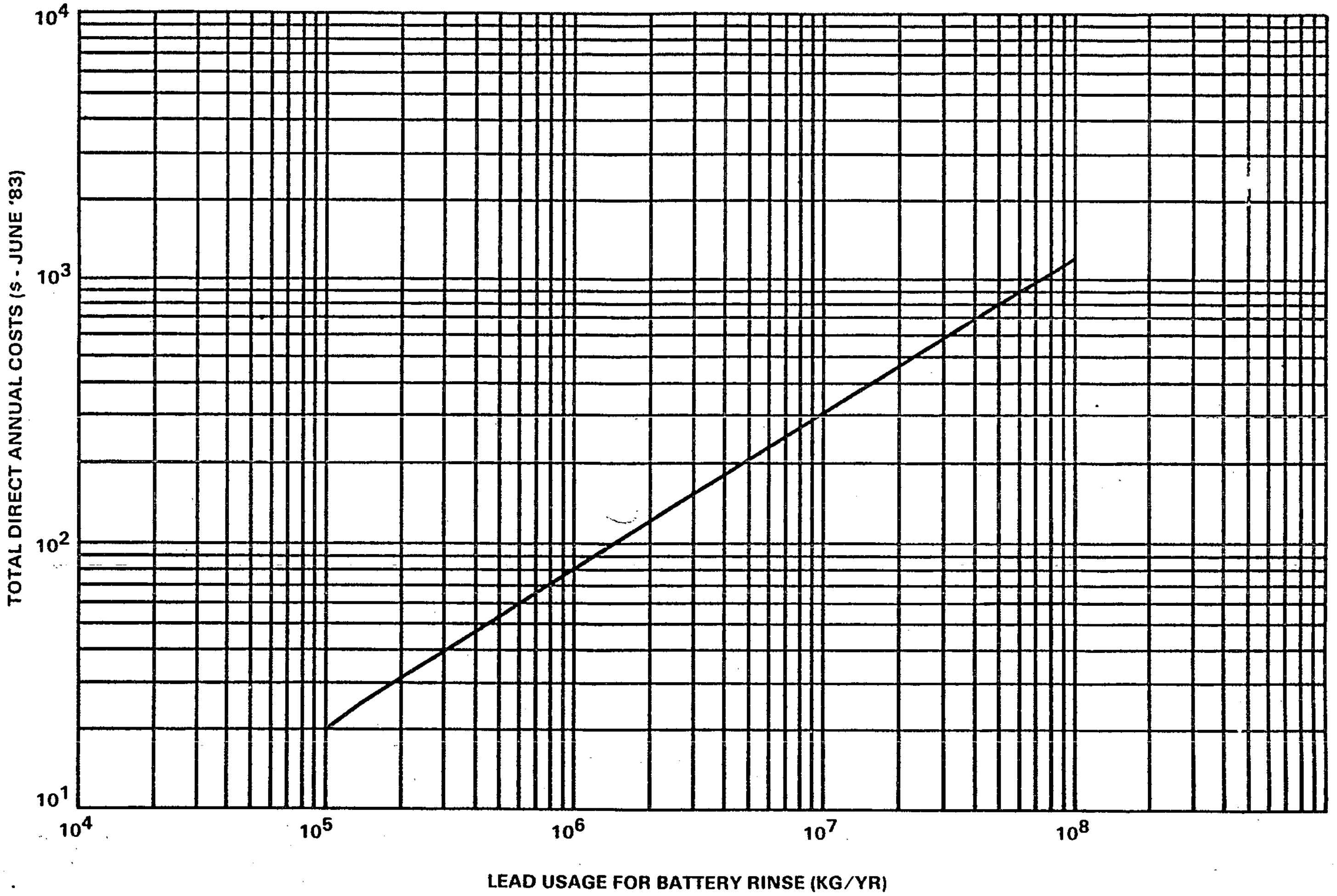


FIGURE VIII-10
ANNUAL COSTS FOR REUSE OF BATTERY RINSE WATER IN ACID CUTTING

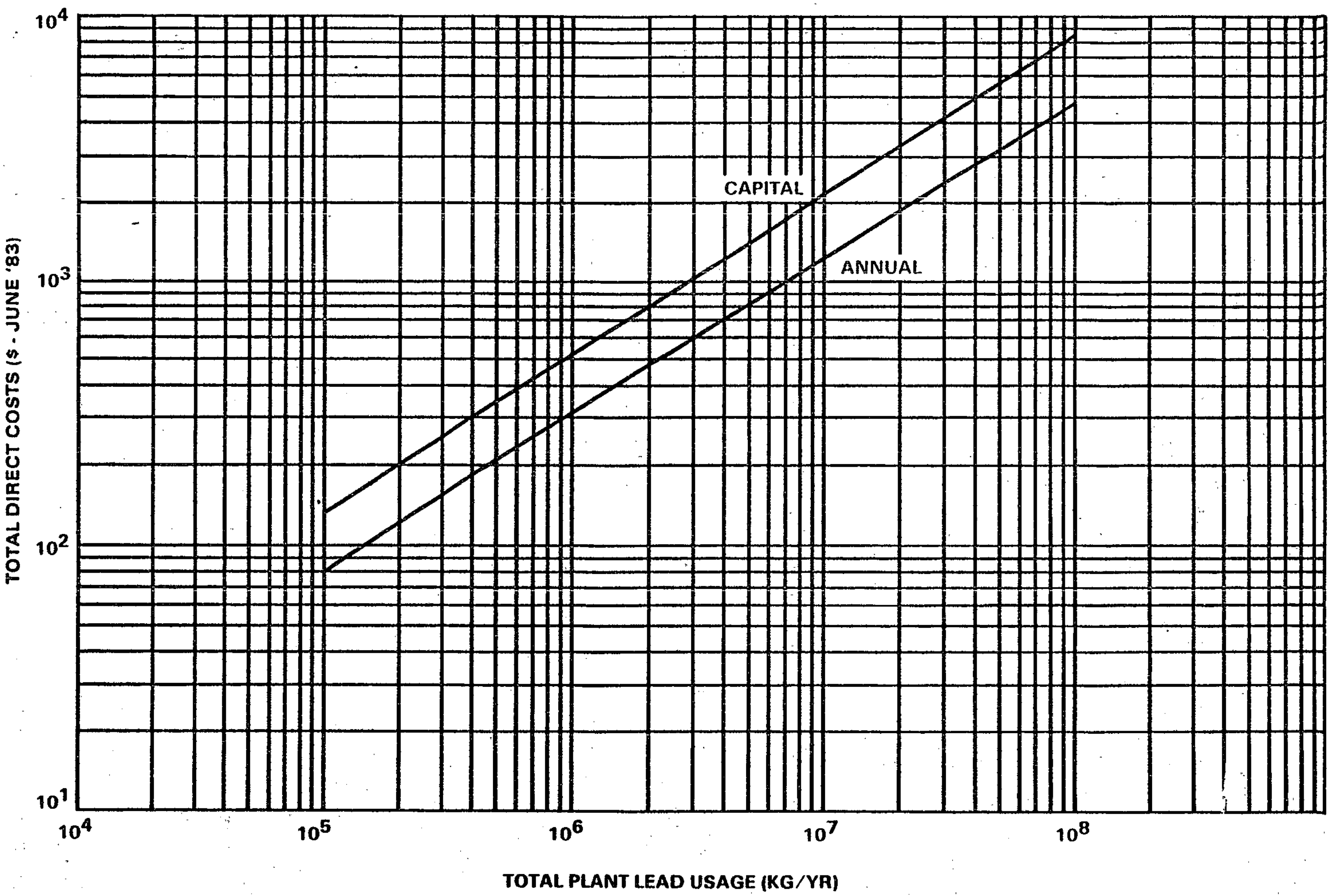


FIGURE VIII-11
COSTS FOR POWER FLOOR SCRUBBER WATER SETTLING

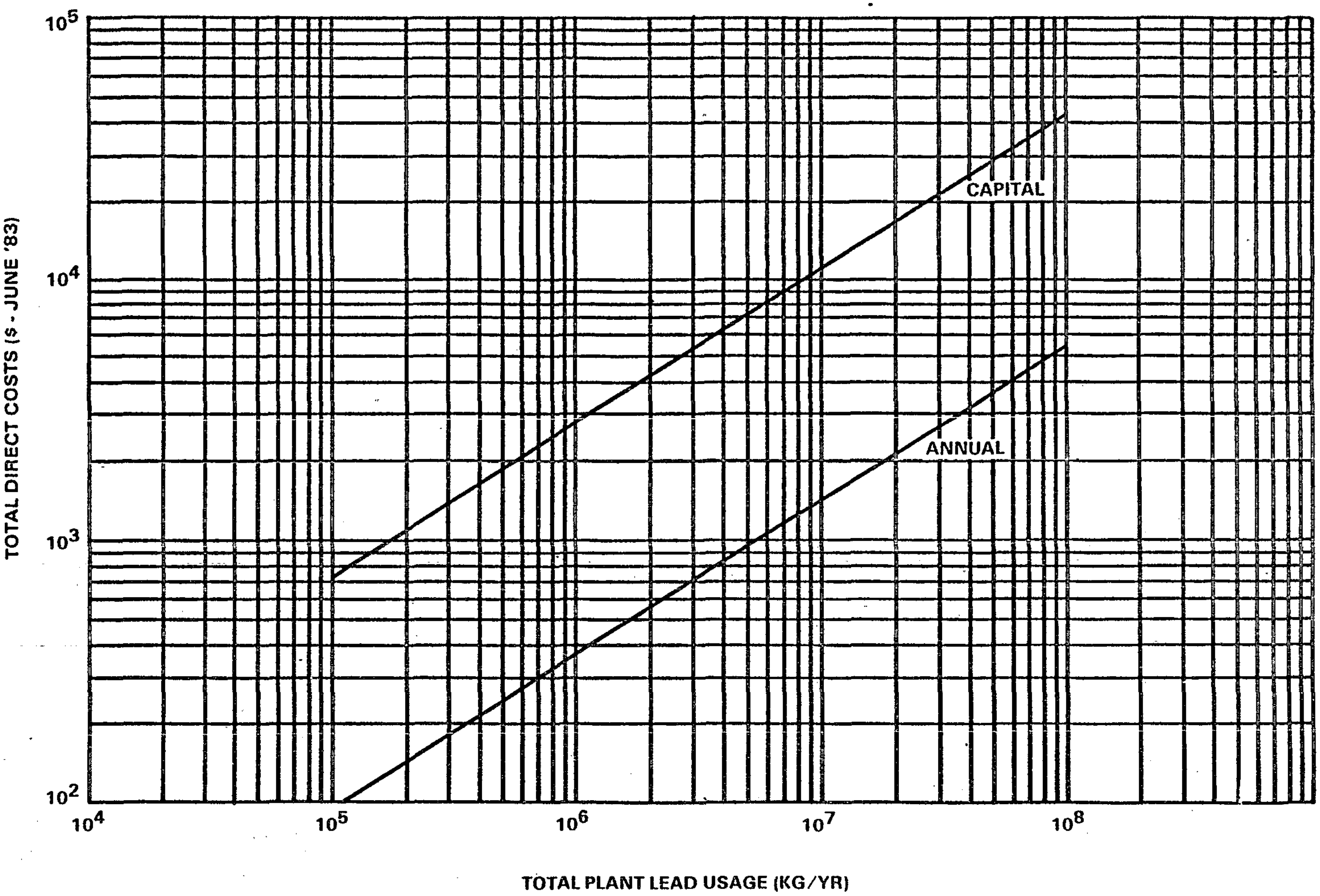


FIGURE VIII-12
COSTS FOR SEGREGATION OF NON-PROCESS WATER FLOWS

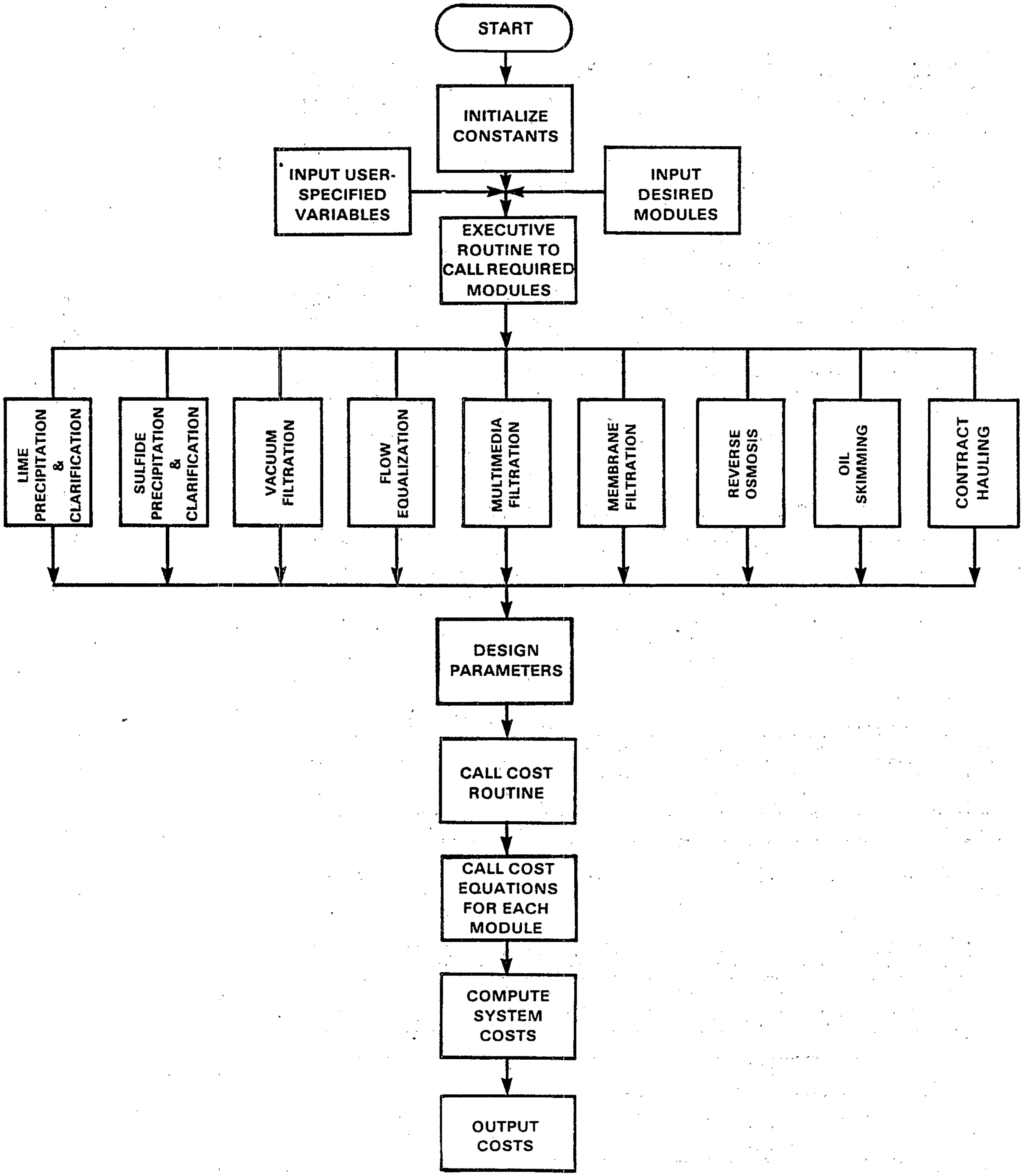


FIGURE VIII-13
GENERAL LOGIC DIAGRAM OF COMPUTER COST MODEL

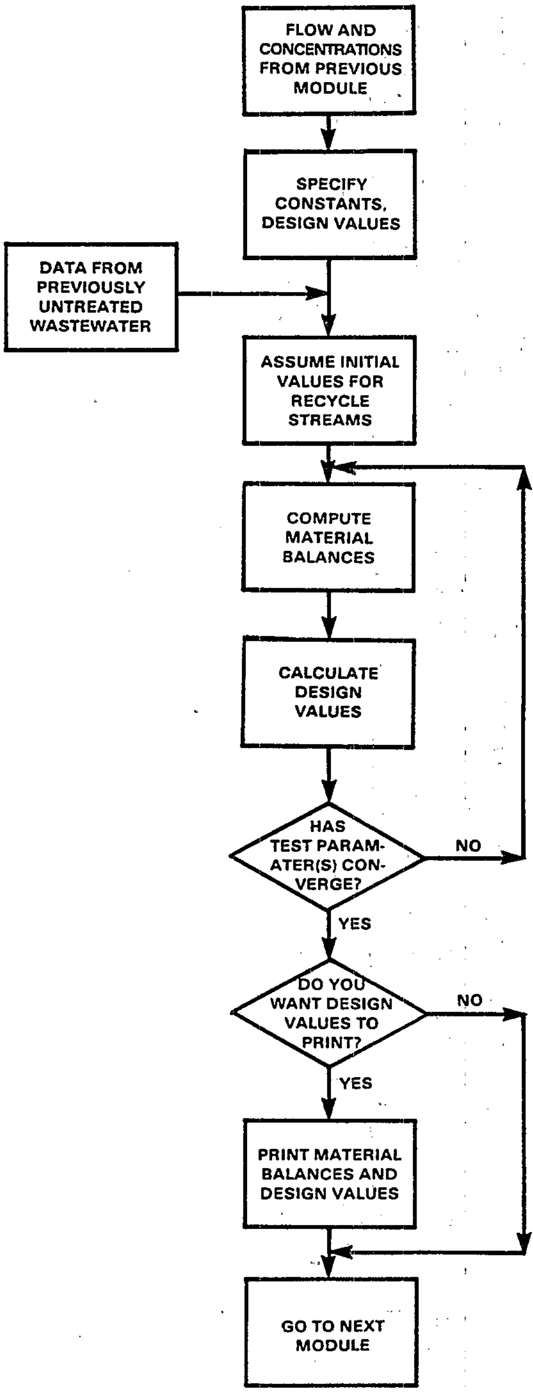


FIGURE VIII-14
LOGIC DIAGRAM OF MODULE DESIGN PROCEDURE

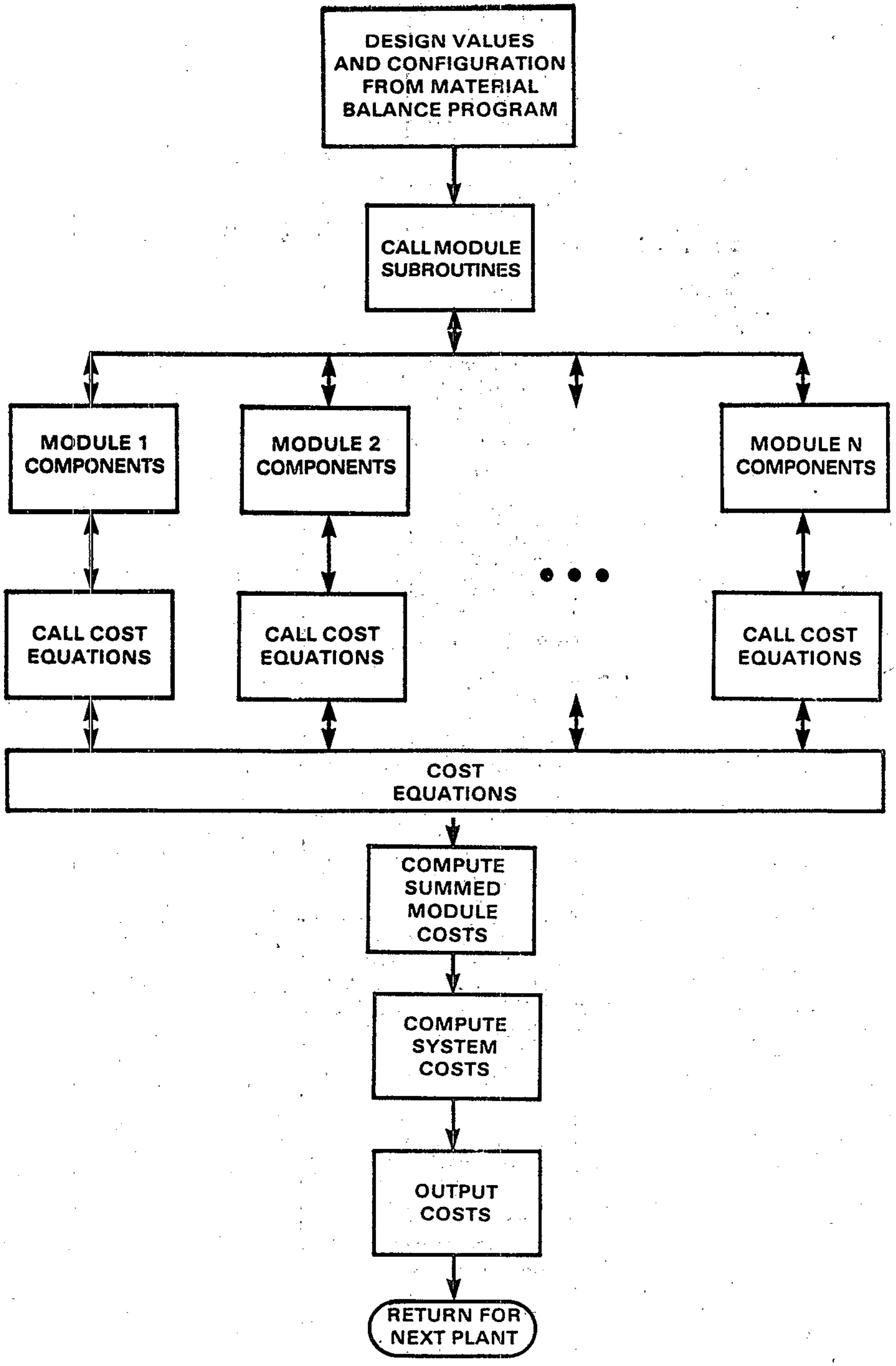


FIGURE VIII-15
LOGIC DIAGRAM OF THE COSTING ROUTINE

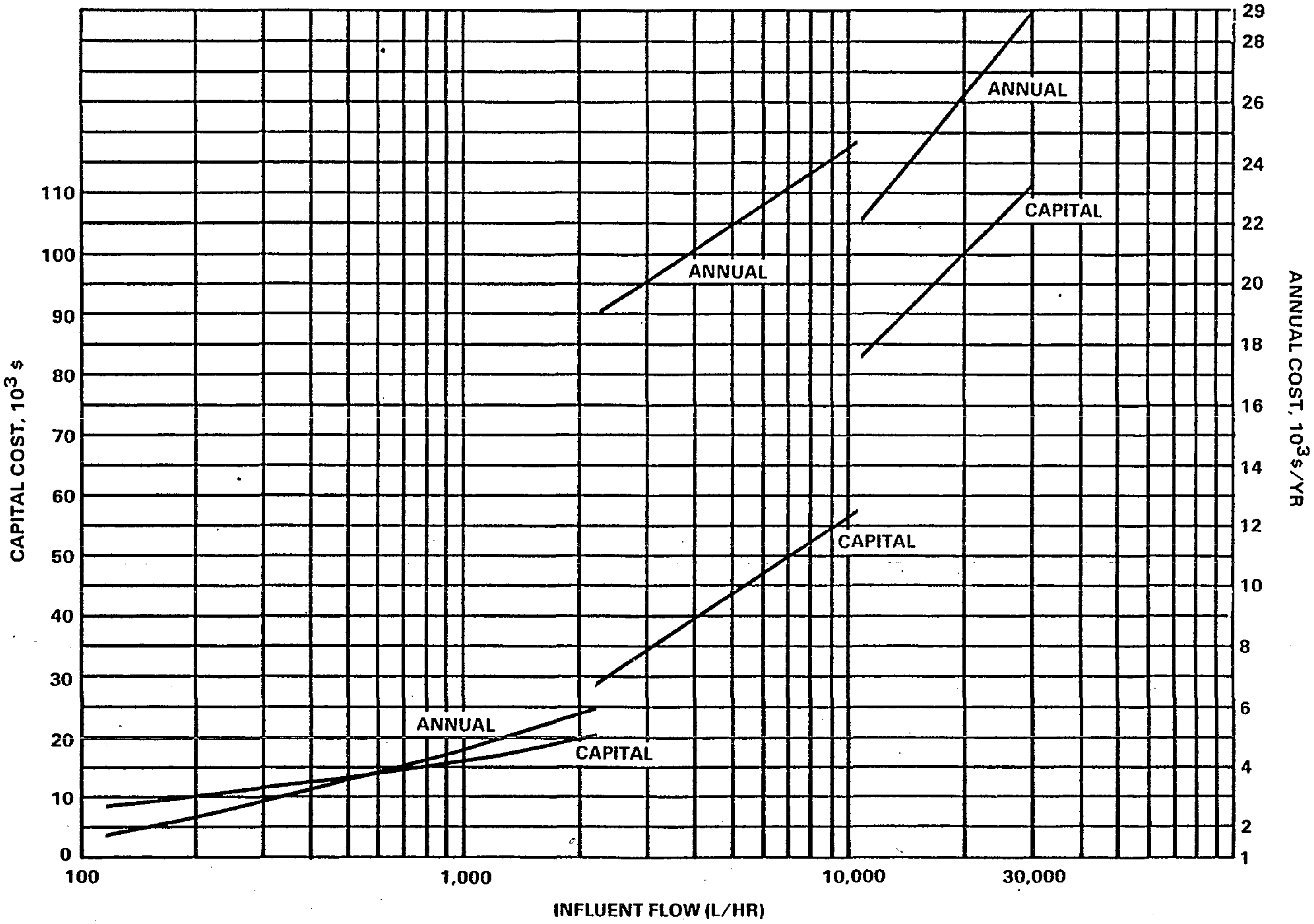


FIGURE VIII—16
COSTS FOR CHEMICAL PRECIPITATION AND SEDIMENTATION

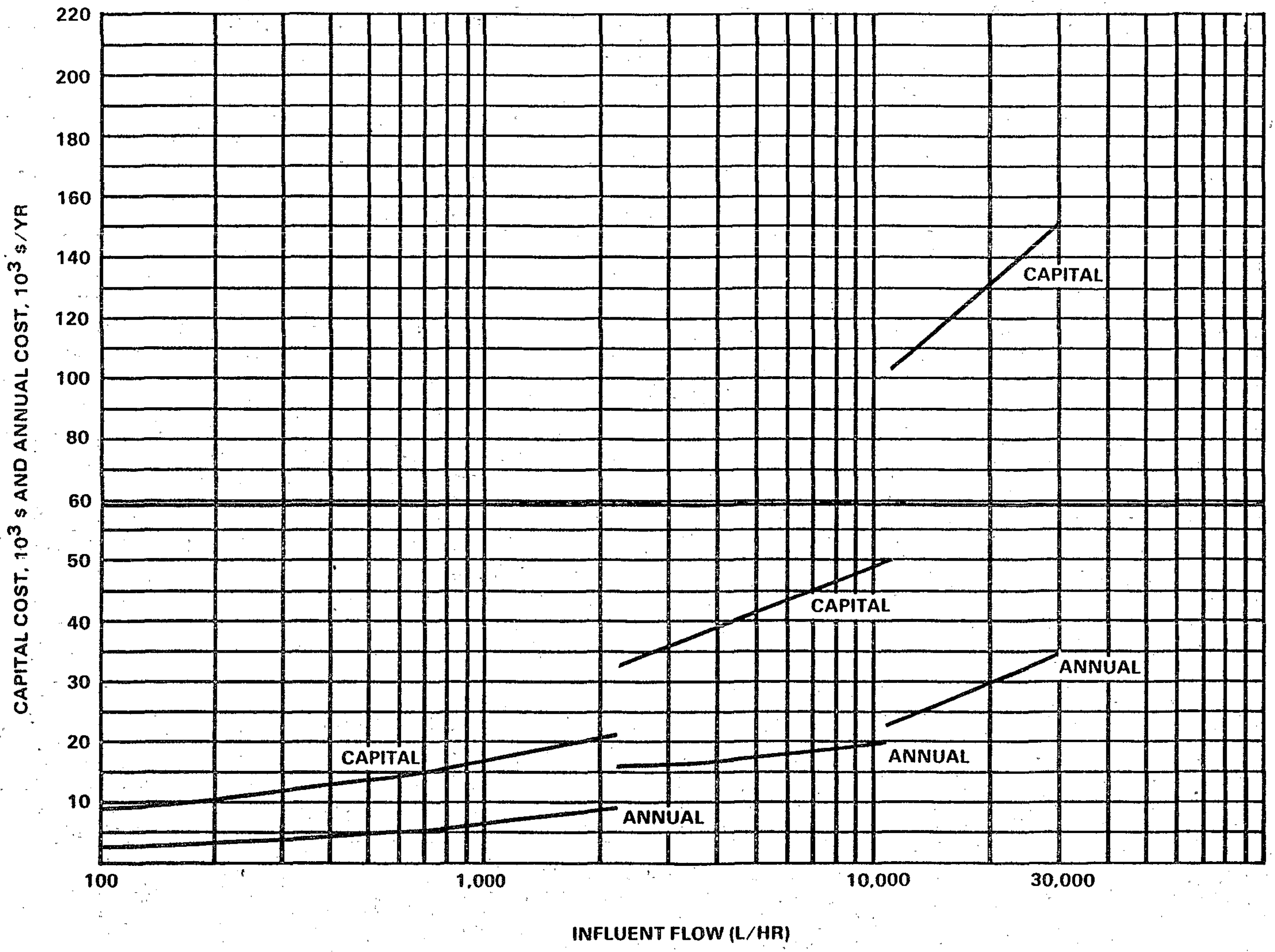


FIGURE VIII-17
COSTS FOR SULFIDE PRECIPITATION AND SEDIMENTATION

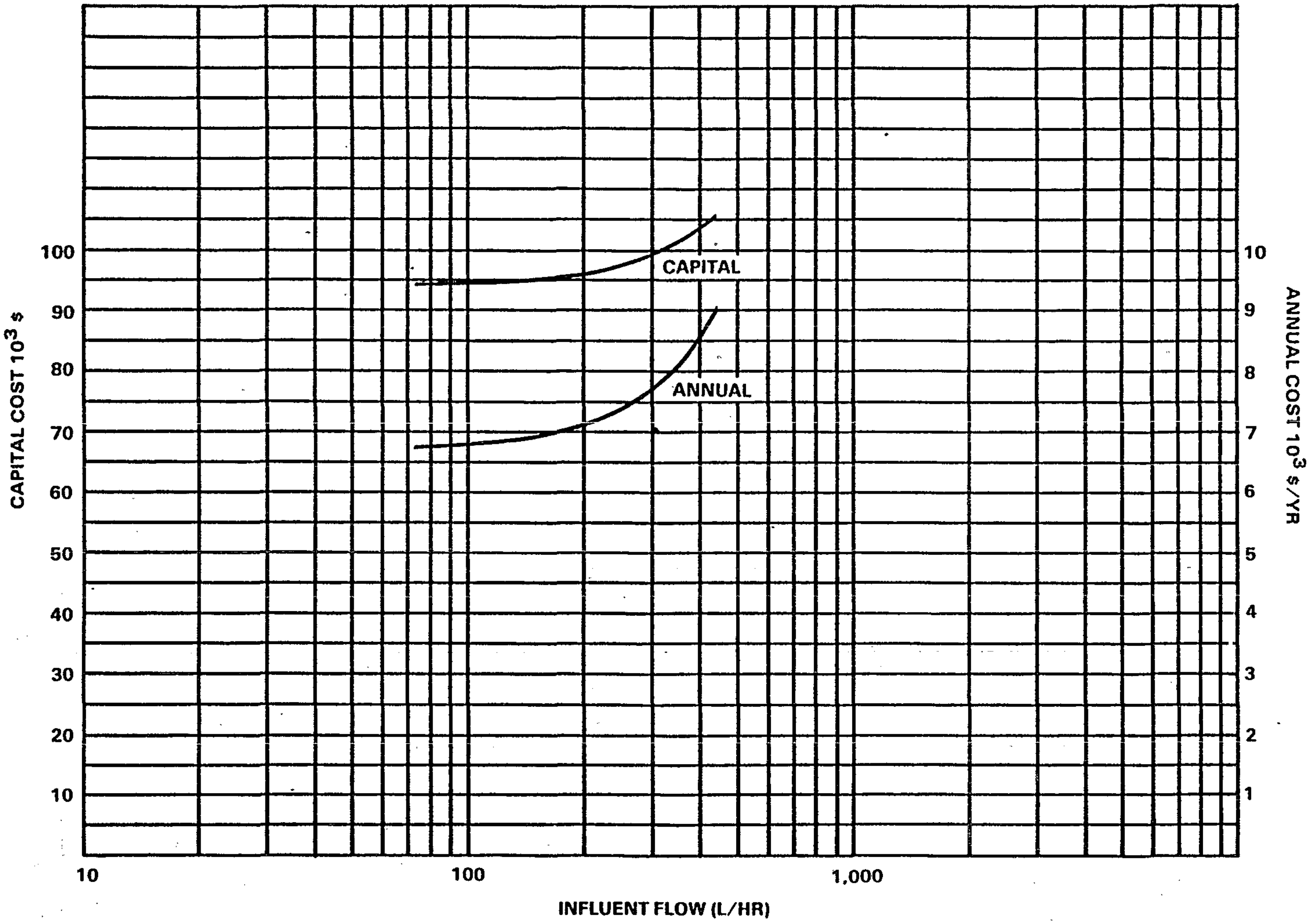


FIGURE VIII-18
COSTS FOR VACUUM FILTRATION

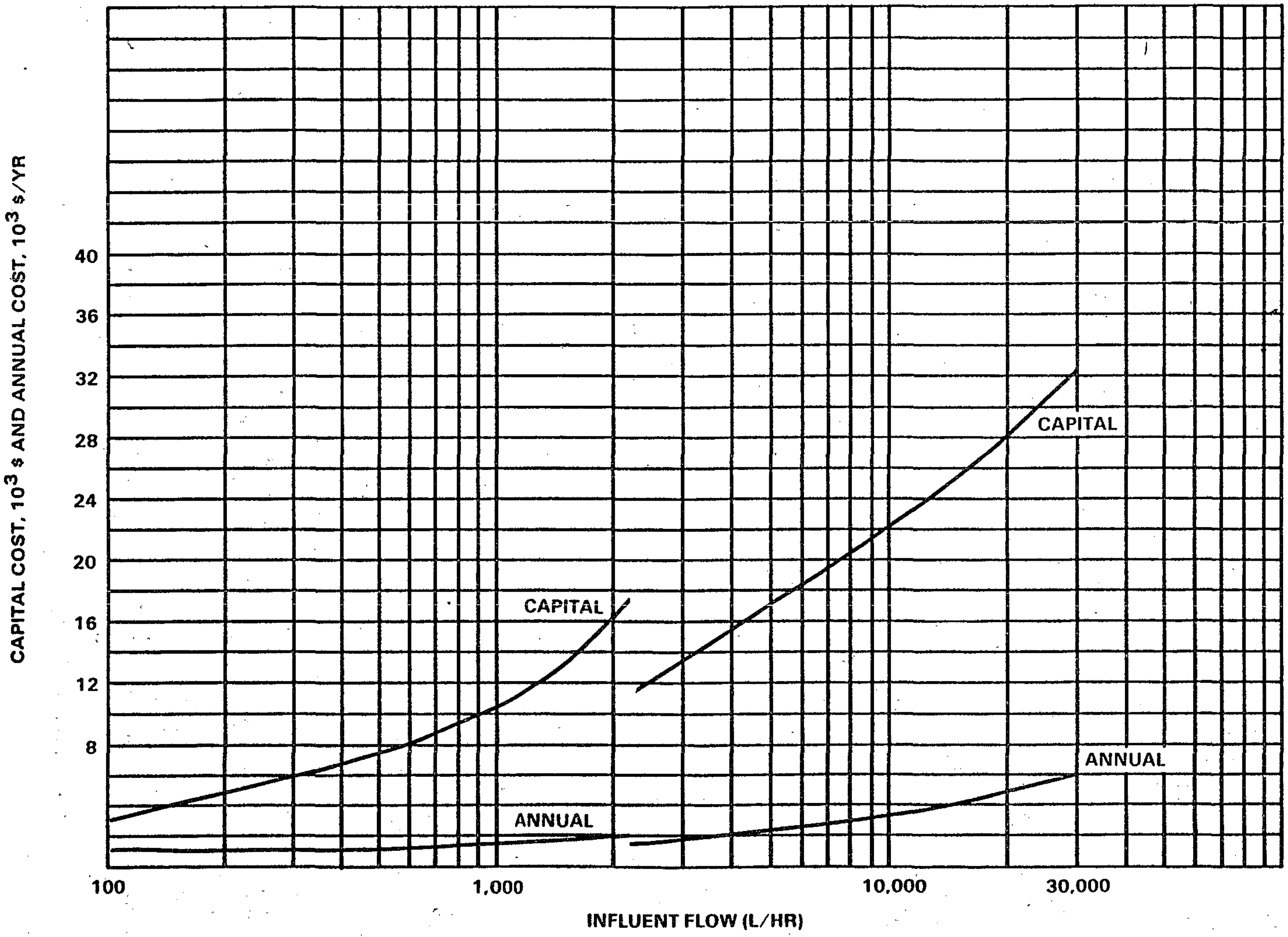


FIGURE VIII-19
COSTS FOR EQUALIZATION

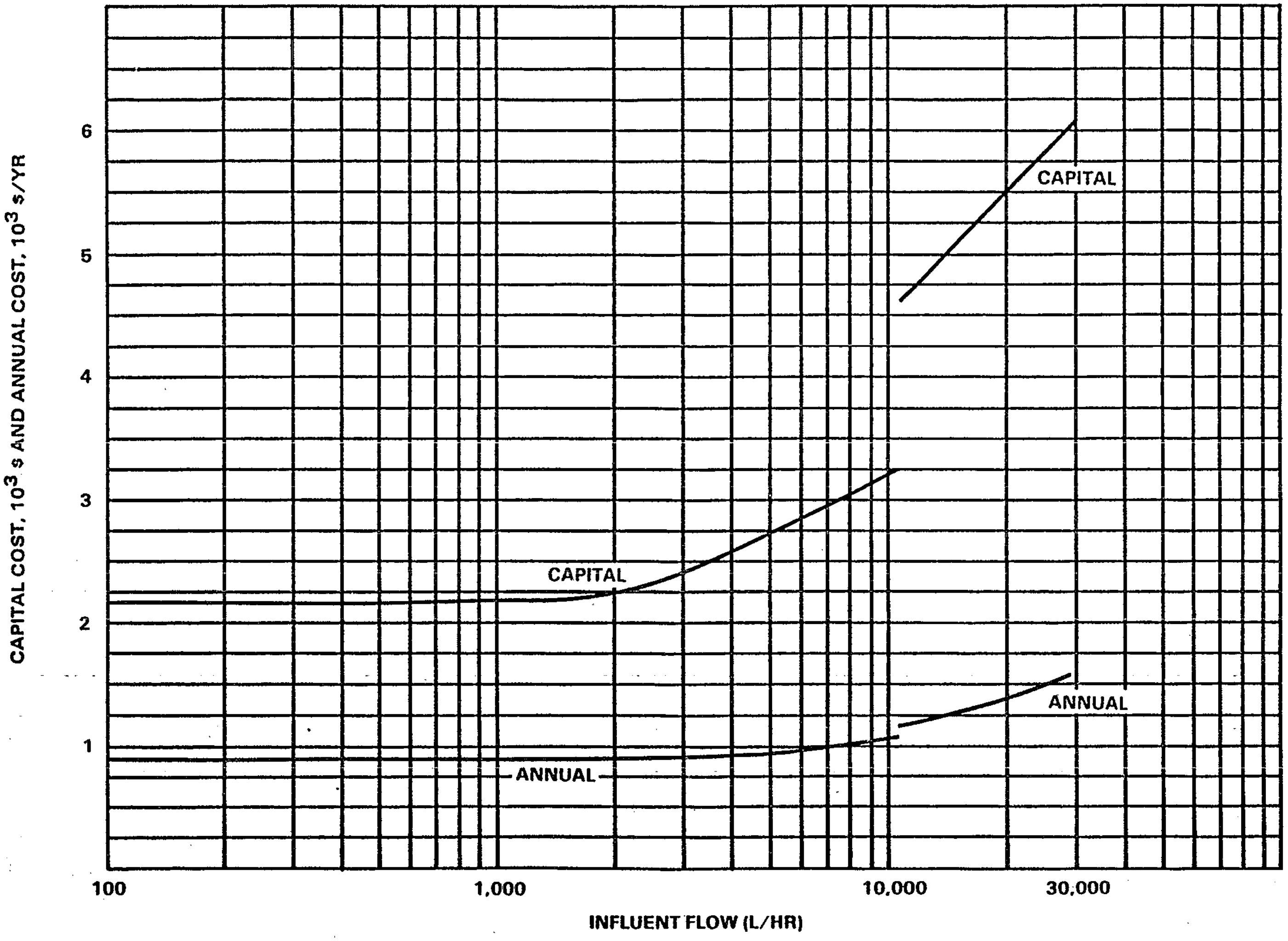


FIGURE VIII-20
COSTS FOR RECYCLING

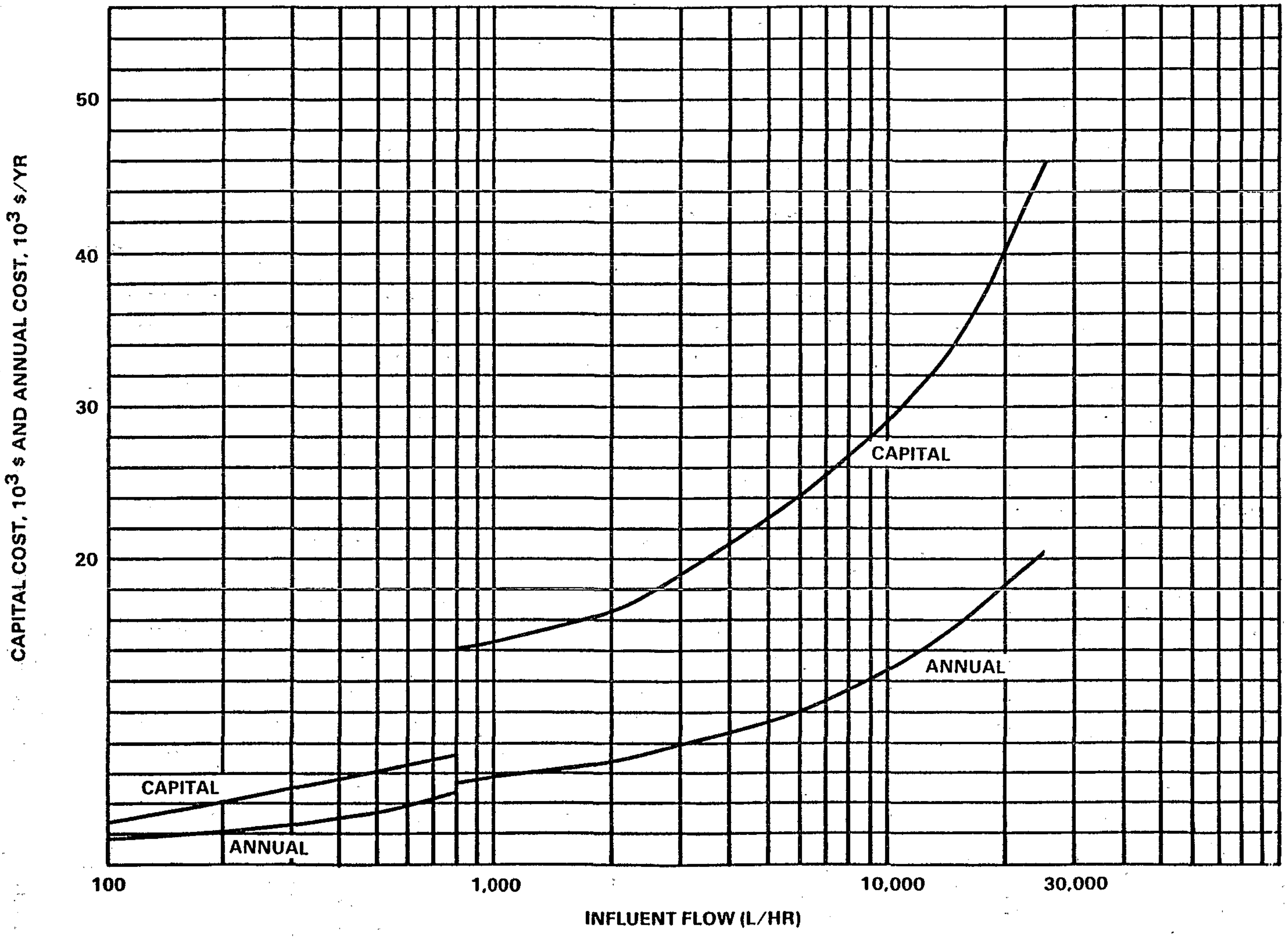


FIGURE VIII-21
COSTS FOR MULTIMEDIA FILTRATION-MEMBRANE FILTRATION

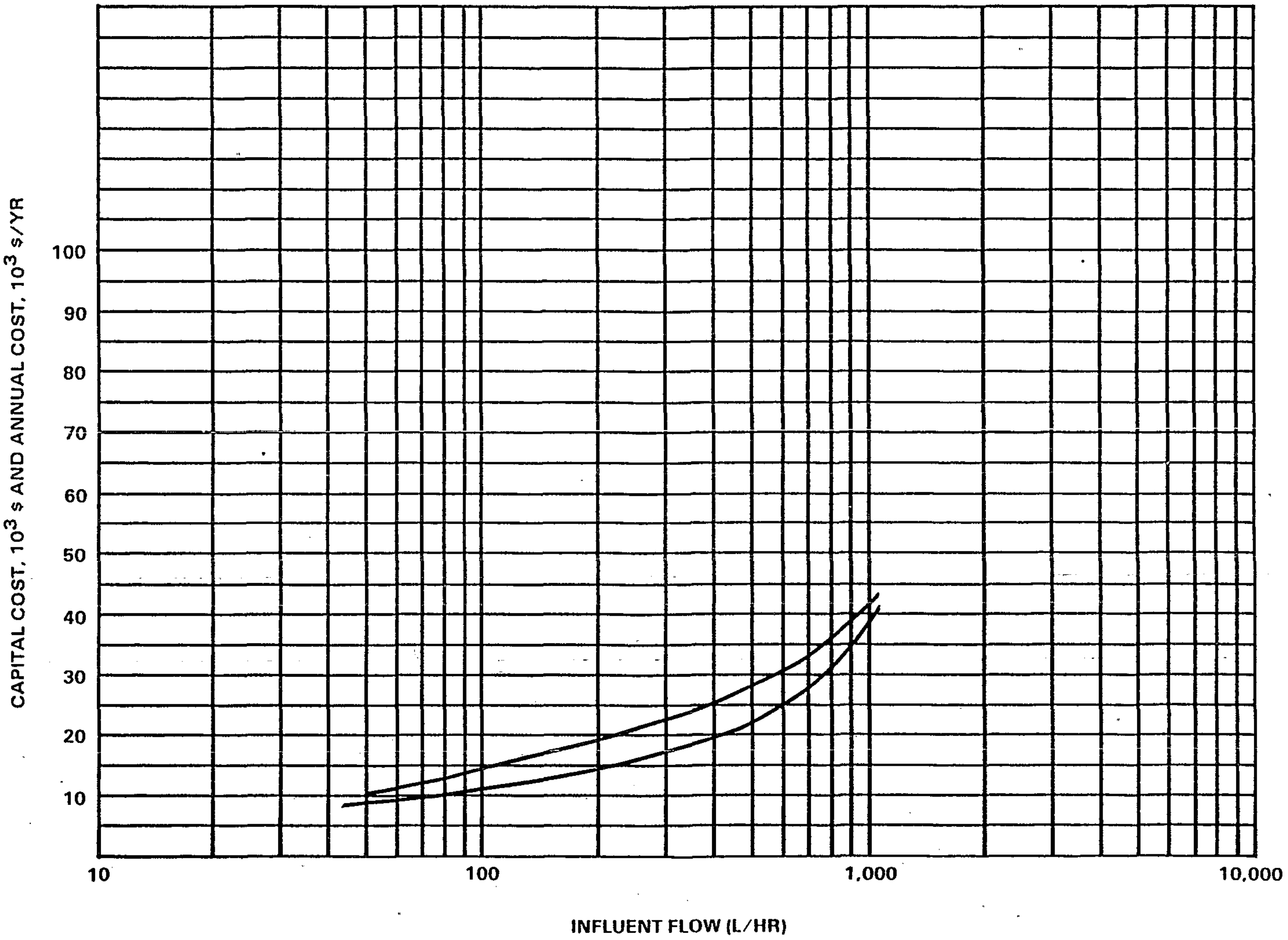


FIGURE VIII-22
COSTS FOR REVERSE OSMOSIS

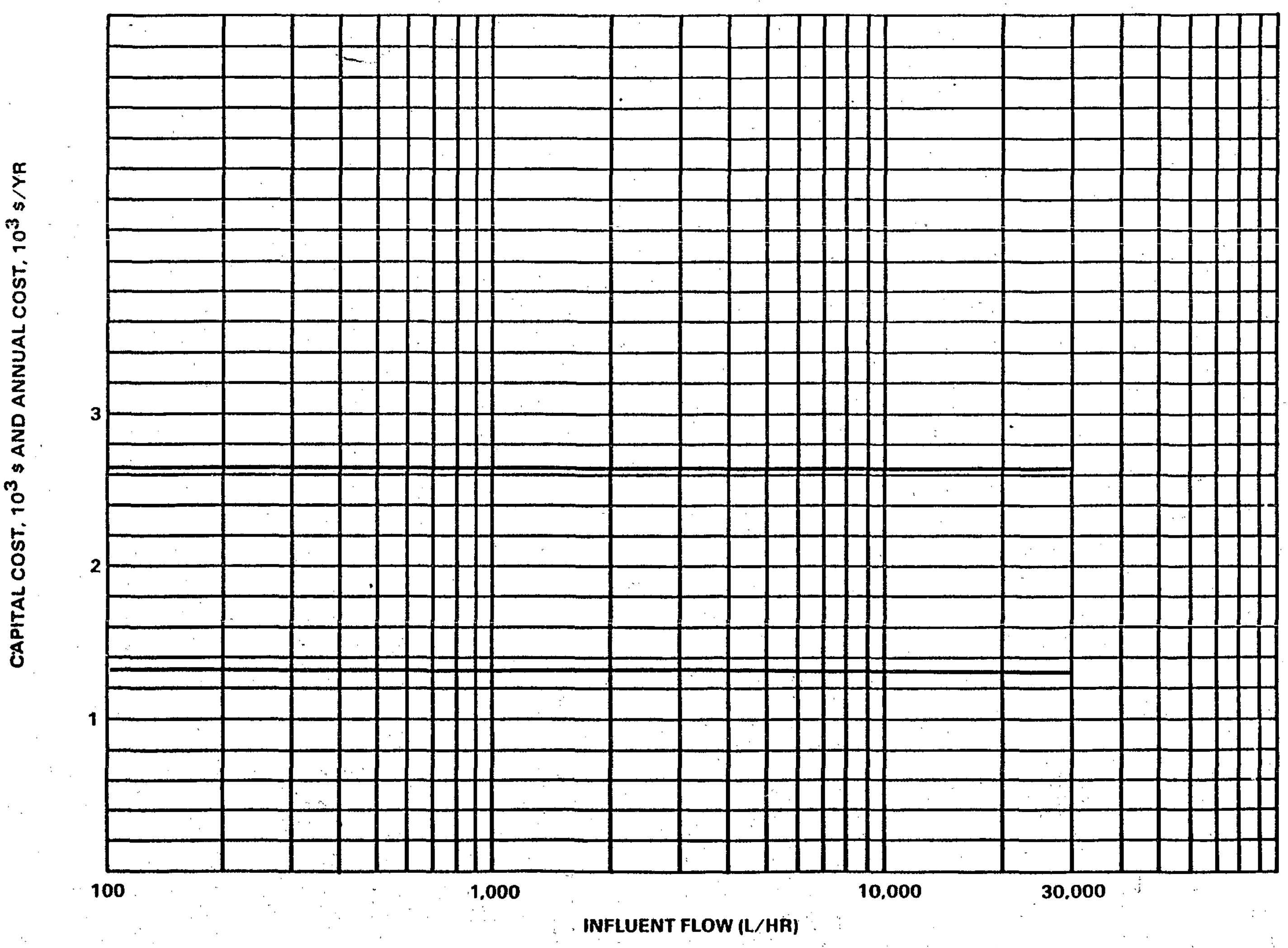


FIGURE VIII-23
COSTS FOR OIL-WATER SEPARATION

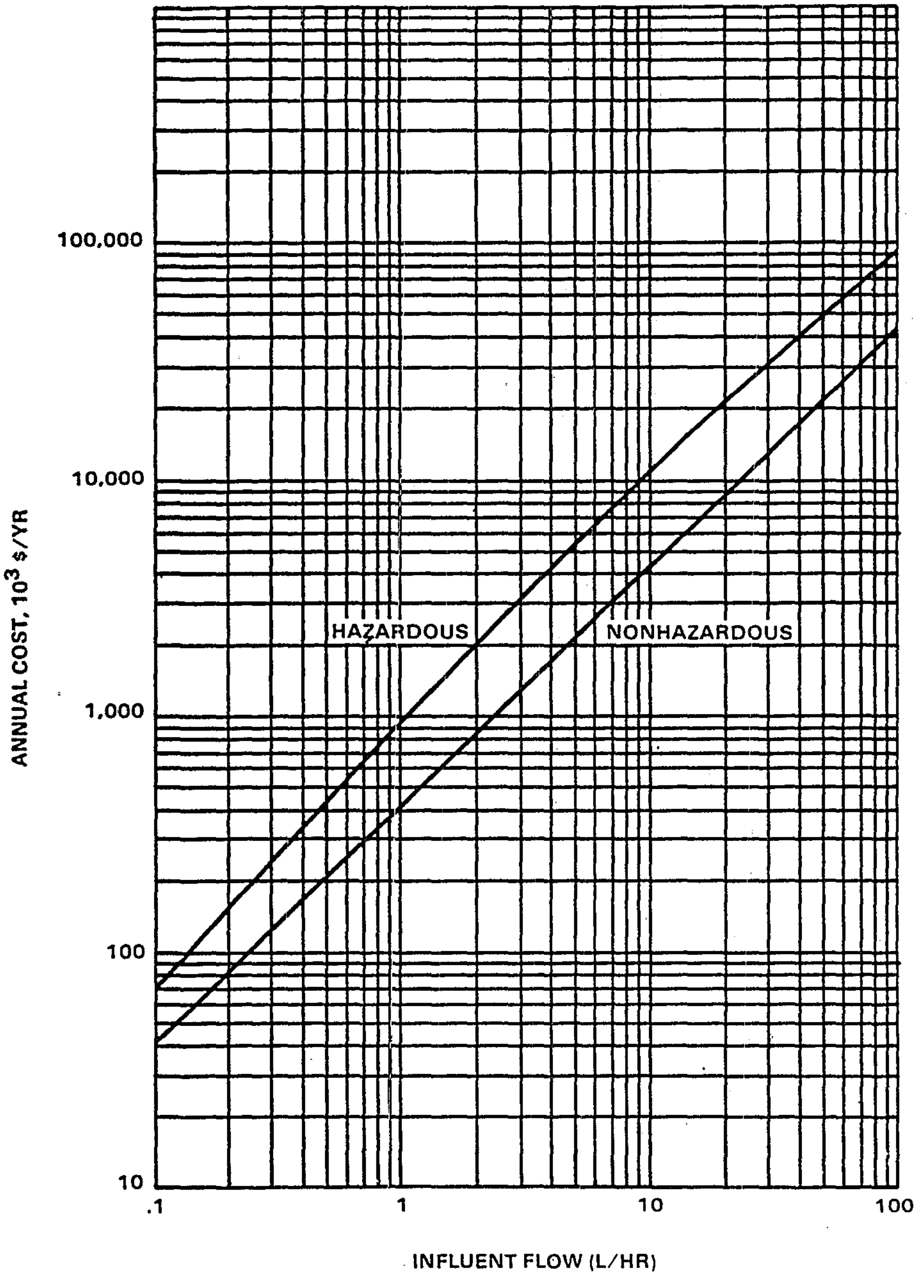


FIGURE VIII-24
COSTS FOR CONTRACT HAULING

SECTION IX

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

This section defines the effluent characteristics attainable through application of the best practicable control technology currently available (BPT), Section 301(b)(1)(A), for the lead subcategory of the battery manufacturing category. BPT reflects the performance of existing treatment and control practices at manufacturing plants of various sizes, ages, and manufacturing processes. Particular consideration is given to the treatment in-place at plants within the subcategory.

The factors considered in defining BPT include the total cost of the 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 average of the best existing practices at plants of various ages, sizes, processes or other common characteristics. Where existing practice is universally 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 transferrable and by a reasonable prediction that the technology will be capable of achieving the prescribed effluent limits. See Tanner's Council of America v. Train, 540 F.2d 1188 (4th Cir. 1976). BPT focuses on end-of-pipe treatment rather than process changes or internal controls, except where such practices are common throughout the category or subcategory.

TECHNICAL APPROACH TO BPT

The entire battery manufacturing category was examined to identify the processes used, wastewater generated, and treatment practices employed in battery manufacturing operations. After preliminary subcategorization and collection of additional information using both dcp forms and specific plant sampling and analysis, the total information about the category was evaluated. On the basis of this evaluation, the subcategorization was revised as described in Section IV to reflect primarily the anode materials. The lead subcategory, encompassing lead acid reserve cells and lead acid storage batteries, is the largest subcategory. The lead subcategory was further subdivided into discrete manufacturing process elements as shown in Table IV-1. These process elements are the basis for defining production normalized flows and pollutant raw waste concentrations. All information was then evaluated to determine an appropriate BPT. Specific factors considered for BPT are:

- The lead subcategory encompasses several manufacturing process elements each of which may or may not generate process wastewater. These elements are divided into groups for anode manufacture, cathode manufacture, and ancillary (or all other) operations considered to be part of battery manufacturing. A plant usually is active in one or more anode process elements, one or more cathode process elements, and in one or more ancillary operations. Process elements within the subcategory are combined in a variety of ways at battery manufacturing plants.

- Wastewater streams from different elements within the subcategory usually share similar pollutant characteristics, have similar treatment requirements and are usually treated in combined systems.

- Most wastewater streams generated in the lead subcategory are characterized by high concentrations of toxic metals.

- Treatment practices vary extensively within the subcategory. Observed subcategory practices include: chemical precipitation of metals as hydroxides, carbonates, and sulfides; sedimentation; and filtration.

Other factors which must be considered for establishing effluent limitations based on BPT have already been addressed by this document. The age of equipment and plants involved and the processes employed are taken into account and discussed in Section IV. Nonwater quality impacts and energy requirements are discussed in Section VIII.

In making technical assessments of data, EPA considered the processes and treatment technology of both indirect and direct dischargers as a single group. An examination of plants and processes did not indicate any process or product differences based on wastewater destination. Hence, descriptions of applicable technology options for direct dischargers, are referred to when describing indirect discharger applications.

The development of BPT mass limitations for the lead subcategory was designed to account for production and flow variability from plant to plant. The production normalizing parameter (pnp) for the lead subcategory was determined to be the weight of lead used for all processes except truck wash where weight of lead in trucked batteries was selected as is discussed in Section IV. Each process element within the subcategory was then analyzed, (1) to determine whether or not operations included in the element generated wastewater, (2) to determine specific flow rates generated, and (3) to determine the specific production normalized flows (mean, median or weighted average) for the process element. This analysis is discussed and summarized in Section V.

Normalized flows were analyzed to determine which flow was to be used as part of the basis for BPT mass limitations. The selected flow (sometimes referred to as a BPT regulatory flow or BPT flow) reflects the water use controls which are common practices within the subcategory based upon dcp, industry survey and plant visit data. All of the flow data used in establishing this regulation for each process element are presented in Section V.

Significant differences between the mean and median reflect a data set which has skewed or biased a wide range of points. When even one data point (for a small data set) or several data points (for a large uniform data set) have an abnormally high flow (improper water control) or unusually low flow (extensive in-process control or process variation), the average or mean may not represent subcategory practice. In cases where there was evidence that data were atypical, use of the median value was considered as a means of minimizing the impact of one point (on a small data base) or several points (on the larger data base). In general, the median is used as a part of the basis for BPT mass limitations. In those cases where a method other than the median was used as the BPT flow, specific rationale for its use is presented in the discussion. Factors considered in using the median values include: numerical variations between the mean and median, absolute size of mean and median value within a process element, relative importance of the size of an element to the total subcategory, and an analysis of specific atypical numbers.

Some elements were limited in the amount of flow data available for BPT flow analysis. These elements are characteristically those where a large fraction of the subcategory is involved in the activity but flow values are available for only a few sites. These elements are mold release formulation equipment wash, laboratory, handwash, respirator wash, laundry, and wet air pollution control. Flows for these elements were obtained from site visits and equipment vendor information as they were generally not reported in the dcp's or industry surveys. To obtain the BPT flow, the general procedure was to calculate the average flow per site for sites where flow information was available; the average flow per site was converted to an annual basis; the annual flow per site was converted to total annual flow using the number of sites reporting the element; the total annual flow was then divided by the sum of individual site lead use values using the most updated values available, 1982 or dcp (1976). In some cases, flows were first normalized on the basis of plant personnel for handwash, or respirators for respirator wash. These average flows were then converted to the total site flow using the appropriate industry survey data, prior to conversion to annual flow. In this way, all information provided was used.

Plants with existing flows above the BPT regulatory flow may have to implement some method of flow reduction in order to achieve the BPT limitations. In many cases this will involve improving housekeeping practices, better maintenance to limit water leakage, or reducing excess flow by turning down a flow valve. In other cases, the plant may need to install systems to recirculate water. As discussed in Section VIII, costs for this subcategory include recycle systems for a number of process operations.

The BPT model treatment technology assumes that all (nonsegregated or nonrecycled) wastewaters generated within the subcategory are combined for treatment in a single or common treatment system for that subcategory even though flow and sometimes pollutant characteristics of process wastewater streams varied within the subcategory. A disadvantage of common treatment is that some loss in pollutant removal effectiveness will result where waste streams containing specific pollutants at treatable levels are combined with other streams in which these same pollutants are absent or present at very low concentrations. Since treatment systems considered at BPT were primarily for metals and suspended solids removal, and existing plants usually had one common treatment system in-place, a common treatment system for this subcategory is reasonable in terms of cost and effectiveness. Both treatment in-place at battery plants and treatment in other categories having similar wastewaters were evaluated. The BPT treatment systems considered consisted of oil skimming, chemical precipitation, and settling. These treatment systems when properly operated and maintained, can reduce various pollutant concentrations to specific levels for each pollutant parameter. Derivation of these concentrations achievable by specific treatment systems are discussed in Section VII and summarized in Table VII-21 (page 418).

The overall effectiveness of end-of-pipe treatment for the removal of wastewater pollutants is improved by the application of water flow controls within the process to limit the volume of wastewater requiring treatment. The controls or in-process technologies recommended at BPT include only those measures which are commonly practiced within this subcategory and which reduce flows to meet the production normalized flow for each process element.

Mass-based limitations have been determined to be the most appropriate approach for regulating the lead subcategory. Concentration-based limitations limit only the concentration of pollutants in the effluent from the model treatment technology, whereas mass-based limitations limit the total mass of pollutants discharged (the product of achievable concentration and flow). Significant reductions in pollutant discharge can be achieved in this subcategory by the establishment of regulatory flows. The concentrations achievable by the model treatment technology are achievable over a wide range of influent concentrations. Therefore, even in situations where decreased water discharge is achieved by recycle (potentially resulting in more concentrated pollutant levels in the wastestream), the effluent concentrations will still be low. The resulting mass discharge of pollutants will be much lower than those which would be achieved by only concentration based limitations, the achievement of which does not require flow reduction.

For the development of effluent limitations, mass loadings were calculated for the process elements within the lead subcategory. This calculation was made on an element by element basis because plants in this subcategory are typically active in multiple wastewater producing process elements; pollutants generated and flow rates can vary for each process element. The mass loadings (milligrams of pollutant per kilogram of pnp - mg/kg) were calculated by multiplying the BPT normalized flow (l/kg) by the concentration achievable using the BPT model treatment (mg/l) for each pollutant parameter considered for regulation at BPT. The BPT normalized flow for the lead subcategory is based on the median of all applicable data (except for elements with limited flow data) rather than the average of the best plants.

The following method is used to calculate compliance with the BPT limitation. The allowable mass discharge for each process element is determined by multiplying the allowable mass discharge limitation (mg/kg) for that process element by its level of production (in kg of production normalizing parameter). The allowable mass discharge for a plant is then calculated by summing the individual mass discharge allowances of the process elements performed at the plant. The actual mass discharge of the plant is calculated by multiplying the effluent concentration of the regulated pollutant parameters by the total plant effluent flow. The actual mass discharge can then be compared against the allowable mass discharge.

SELECTION OF POLLUTANT PARAMETERS FOR REGULATION

The pollutant parameters selected for regulation in the lead subcategory were selected because of their frequent presence at treatable concentrations in raw wastewater. Specific raw waste characteristics from the process elements are described in Section V and are displayed in Tables V-5 to V-31 (pages 178 to 210). Total raw waste characteristics for all of the plants sampled in this subcategory are presented in Table V-34. Tables VI-1 and VI-2 (page 296 and 301) summarize the pollutants which were considered for regulation. The pollutants which are present at treatable concentrations in lead subcategory raw wastewaters include antimony, cadmium, chromium, copper, lead, mercury, silver, nickel, zinc, aluminum, iron, manganese, oil and grease, and TSS. However, because antimony, cadmium, chromium, mercury, silver, nickel, zinc, aluminum, and manganese are found in smaller quantities and will be removed by lime and settle treatment simultaneously with removal of the regulated pollutants, they are not regulated at BPT.

The pollutant parameters selected are toxic metals (copper and lead), iron, suspended solids, and oil and grease. pH is selected as a treatment control parameter. As discussed in Section VII, the importance of pH control for metals removal cannot be overemphasized. Even small excursions away from the optimum pH range (in most cases 8.8 - 9.3) can result in less than optimum functioning of the system. To accommodate this operating pH range (8.8 - 9.3) without requiring a final pH adjustment the effluent pH range is shifted from the commonly required 6.0 - 9.0 to 7.5 to 10.0. With the application of lime and settle technology, the concentration of regulated pollutants will be reduced to the concentration levels presented in Table VII-21.

Total suspended solids, in addition to being present at high concentrations in the raw wastewater is an important control parameter for metals removal in chemical precipitation and settling treatment systems. The metals are precipitated as insoluble metal hydroxides, and effective solids removal is required in order to ensure reduced concentrations of toxic metals in the treatment system effluent. Total suspended solids are also regulated as a conventional pollutant to be removed from the wastewater prior to discharge. Oil and grease is regulated under BPT since some wastestreams generated at lead battery plants contain high concentrations of oil and grease (as shown in Section V).

Lead has been selected for regulation under BPT since it is found at high concentrations in process wastestreams.

Copper has been selected for regulation under BPT since it and lead are the predominant toxic metals present in lead battery manufacturing wastewaters. Copper may be introduced into battery manufacturing wastewaters by corrosion of process equipment containing copper, such as cables and leads used in charging operations.

Iron is being regulated because it was found in treatable concentrations in all total raw wastewater streams. These high concentrations are attributable to corrosion of process equipment and charging racks by sulfuric acid.

PRODUCTION OPERATIONS AND DISCHARGE FLOWS

The lead subcategory includes the manufacture of a variety of battery types, almost all of which are made of the same principal raw materials: lead, lead oxides, and sulfuric acid electrolyte. The plants within the subcategory vary widely in their wastewater discharge volumes, reflecting process variations and a variety of water use controls and water management practices. All lead subcategory process elements identified in Table IV-1 (page 105) generate process wastewater. Specific wastewater sources are identified in Figure V-2 (page 170). Production normalized flow data for all of these process elements are presented in Section V. The same production normalizing parameter (total lead use) can generally be used for all process elements in this subcategory except truck wash since water use is related to lead use.

Table IX-1 (page 557) presents the normalized discharge flows that form part of the basis for the pollutant mass discharge limitations for each process element. These normalized flows are generally equal to the median normalized flows presented in Table V-3 (page 174) (except for elements with limited flow data) and are indicative of half of the plants active in a particular process element. Median statistical analysis was used for this subcategory because of the nature of the data base. For the lead subcategory, which is a large data base, the use of the median values more realistically reflects where zeroes are in fact, representative of common industry practice. Table IX-2 (page 559) summarizes the number of plants included in each process element, the number which have zero discharge, and how zero discharge is achieved. Therefore the use of the median in this subcategory is reasonable.

Anode and Cathode Process Elements

All anode and cathode process element BPT regulatory flows (except grid manufacturing regulatory flows) were calculated by using the median of plant-reported site specific flow rates which were individually normalized by the site's lead use. The lead use value chosen was the most up to date value available, i.e., 1982 or dcp (1976). Plant-reported flow rates were obtained from dcp data for all anode and cathode process elements except where more recent data were available. Certain dcp values were updated from information obtained from trip reports (before and after proposal), plant contacts, and plant comment information. The number of production normalized flows (l/kg) varied among these process elements; the specific supporting data are reported in Section V.

Leady Oxide Production. Information on water use in leady oxide production was reported by 41 plants of which 29 plants reported zero discharge for this process element. Wastewater was reported to originate from leakage in ball mills, shell cooling contact cooling, and wet scrubbers for air pollution control. (Scrubbers are considered under the wet air pollution control process element). Many plants generating leady oxide using balls mills or Barton processes use only non-contact cooling water for bearings, extensive recycle, and dry bag houses for pollution control and therefore produce no process wastewater. A zero discharge allowance has been established for this process element at BPT based upon the fact that 70.7 percent of the plants which reported data for this process element discharge no wastewater.

Grid Manufacture. Process wastewater is generated from four grid manufacturing operations: direct chill casting (continuous strip casting), lead rolling, mold release formulation, and grid casting. In direct chill casting, contact cooling water is used to quickly cool the cast lead strip. The contact cooling water is collected and continually recirculated. The water in this system is generally batch dumped. Five plants report the use of this casting technique and one plant provided flow information for this wastestream. This plant was presented as the model to be used for all five plants. The BPT regulatory flow has been established as 0.0002 l/kg, the production normalized flow for this one plant.

In lead rolling, an emulsion is used to lubricate the rolling mills. This emulsion is contract hauled to land disposal off-site by all five lead battery plants which report this activity. Lead rolling is included under the battery manufacturing category but is not specifically regulated because there are no known dischargers. Guidance is provided in the event that plants which perform lead rolling find the need to discharge this wastewater. A regulatory flow of 0.006 l/kg of lead used in batteries (0.0233 l/kg lead rolled) has been established for guidance should plants find the need to discharge this wastewater. This flow is based on sampling data from one plant.

Process wastewater from grid casting originates from mold release formulation and wet air pollution control in some plants. The wet air pollution control operation is addressed under that respective process element. The formulation of mold release agents can generate process wastewaters by cleaning equipment after mixing batches of the release material. Flow data (average flow per plant) for the mold release formulation process were obtained from two companies that reported discharge of this wastewater at their plants. This represents data on 29 plants all of which reported a discharge of wastewater. The BPT regulatory flow for mold release formulation has been established at 0.006 l/kg. This was obtained by: (1) multiplying the company specific flow by the number of respective plants in the company and (2) dividing this total flow by the sum of the company-specific productions to obtain a company-specific production normalized flow. The two resulting company-specific PNFs were then averaged to obtain the BPT flow.

Paste Preparation and Application. Information on water use for the paste preparation and application process element was reported by 100 plants, of which 57 reported zero discharge of wastewater. 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 sent to a smelter for the recovery of lead. After settling, the wastewater can be used either in paste formulation or pasting area floor and equipment washdown. A zero discharge allowance has been established for this process element at BPT because the elimination of process wastewater discharge from paste preparation and application areas by collection, settling, and reuse is commonly practiced by plants in the lead subcategory. Discharges from wet scrubbers used to control fumes from paste mixing at some plants are included in the wet air pollution control process element.

Curing. Eighty-seven of the 97 plants supplying data reported zero discharge of wastewater from plate curing. Wastewater generated by the other ten plants was a result of steam or controlled humidity curing with discharge. Steam curing and humidity curing processes were observed at existing plants which currently achieve zero discharge from this process element. This is achieved by collection and recirculation methods for the wastewater, as described in Section VII. Therefore, a zero discharge allowance has been established for this process element.

Closed Formation. The closed formation process includes three distinct elements: single fill formation and double fill formation (which are collectively known as closed formation of wet batteries), and fill and dump formation (also known as closed case formation of damp batteries). The closed formation process generates wastewater from a variety of sources as discussed in Section V but primarily from the rinsing of battery cases. A few plants in the subcategory reported and were observed to use large amounts of cooling water. The use of contact cooling water results from the implementation of rapid charging rates, as discussed in Section VII. As discussed in Section V, wet scrubbers used to control fumes from closed formation are included in the wet air pollution control process element.

In the single fill operation, the battery is filled with acid of such specific gravity that, after formation, the electrolyte will be suitable for shipment and operation of the battery. For this process element, 31 of the 43 plants supplying data reported no discharge. Zero discharge is achieved by using low-rate or controlled charging techniques which do not require the use of contact cooling water to dissipate heat generated during battery charging. Effective battery filling techniques are also used to control spills and eliminate the need for battery rinsing prior to charging. A zero discharge allowance has been established for single fill closed formation since zero discharge is indicative of common industry practice for the single fill process.

Even though the final shipping status is different for the double fill and fill and dump processes (wet--with electrolyte vs. damp-without electrolyte), the generation of process wastewater and the pollutant characteristics are essentially similar. In the double fill formation process, the batteries are filled with a low specific gravity electrolyte, charged, and the electrolyte dumped. The batteries are then filled with a higher specific gravity electrolyte for shipping. The reuse of dumped formation acid is a common practice among the lead subcategory plants and is economically beneficial. Contamination of the electrolyte is minimized by limiting spillage and implementing effective acid collection techniques during post-formation 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. Of the 35 plants providing data on the double fill process, seven reported zero discharge of wastewater.

The fill and dump formation process is the same as the double fill process except that a second electrolyte fill is not performed before shipment. Thirteen plants provided information on the fill and dump formation process, of which 12 reported discharge of wastewater.

Because the processes are essentially identical, a BPT regulatory flow has been established for double fill and fill and dump formation combined. The BPT flow, is based on the median of all of the data for the two processes and is 0.45 l/kg lead used.

Open Formation. The open case formation process includes open formation for wet plates and open formation for dehydrated plates.

In the case of open formation for dehydrated plates, the primary source of wastewater is from the rinsing and dehydration of plates. Of the 42 sites which provided information on open dehydrated formation, 40 reported a discharge of wastewater.

The median normalized discharge flow of 11.05 l/kg was selected as the BPT regulatory flow for open case formation for dehydrated plates. The median flow was selected because it is considered to be common industry practice with 50 percent of the plants currently discharging at or below this level.

Open formation for wet plates is frequently used for the manufacture of industrial batteries with large electrodes. Wastewater from this operation is sometimes generated from dumping and not reusing electrolyte after a certain number of formation cycles. Some plants reuse this electrolyte in final battery products; others send it to treatment. Plants also reported area washdown, and rinsing of formed plates as contributing to the discharge from this operation. Of the 16 plants providing information on this process element, ten reported zero discharge of process wastewater. Five of the six discharging plants discharge plate rinsing wastewater, spent electrolyte or both. These plants contend that a discharge of these wastewaters is unavoidable because there is no opportunities in the plant for reuse of the acid or rinse water. Therefore, a BPT regulatory flow of 0.053 l/kg has been established for these waste streams based on the median discharge flow from these five plants. The sixth plant which discharges wastewater from open wet formation was not used to calculate the regulatory flow. This plant reuses spent electrolyte but discharges wastewater from formation area equipment washdown. None of the other plants with open wet formation reported a discharge from equipment washdown. Therefore, flow data from this plant was not used to determine a regulatory flow.

Four of the five plants used to determine the regulatory flow are operated by one company. The frequency of batch electrolyte discharges at these four plants varies from daily discharges to semi-annual discharges. This indicates that the number of formation cycles that electrolyte can be used before dumping is not well defined at this company. To calculate the regulatory flow for open wet formation, it was assumed that electrolyte is batch dumped once per month at these four plants.

Wastewater discharges associated with wet scrubbers used to control fumes generated from open wet formation are included in the wet air pollution control process element.

Plate Soak. Based on data collected in dcps, industry surveys, from site visits and in plant comments received, some plants soak plates usually for heavy industrial batteries in sulfuric acid prior to formation. The plates soaked are relatively thick 0.25 cm (0.10 inch or greater). Occasional dumping of this acid is required generating a small waste stream which must be treated. The BPT regulatory flow for this stream is calculated to be 0.021 l/kg of lead used in batteries that are plate soaked. This number is based on the median of data reported by three plants on the amount of electrolyte dumped.

Ancillary Operations

Regulatory flows for ancillary operations were calculated using either medians of individual plant production normalized flows or a weighted average of flow data available followed by production normalization. The method which was used was dictated by the amount of flow data which were available from lead subcategory plants. Where a few flow rates were measured or reported by plants but the participation by plants in the element is significant, a weighted average was used. This averaging technique varied in accordance with the type of data being used and is discussed for each applicable element. The plants which reported flow data as well as those which reported the process element are presented in Table IX-1. As in the case of the anodes and cathode elements, the production normalized flow data base included dcp data which were updated with data obtained from site visits, plant contacts, and plant comments.

Battery Wash. Battery wash operations produce wastewater as a result of two different process elements - washing with detergent and washing with water only. Nearly all of the plants active in these process elements reported wastewater discharge. Sixty-six plants provided flow data on battery wash of which 44 reported the use of water and 22 reported the use of detergent. Of the plants reporting the use of a detergent wash system, none reported zero discharge of wastewater. The median production normalized discharge flow, 0.90 l/kg, is used as the flow basis for determining the BPT flow for detergent washing of batteries. The median was chosen because 50 percent of the plants are currently maintaining this flow which is considered to be common industry practice. Those plants currently discharging at a flow greater than the median could reduce their flows by additional recirculation of wash solution and rinse water, and by reusing the final rinse as make-up to the detergent portion of the system resulting in discharge from only the detergent wash step.

Of the 44 plants reporting the use of water battery wash systems, 43 reported a discharge of wastewater. The BPT regulatory flow for water washing has been established at the median production normalized flow of 0.59 l/kg. Those plants currently discharging at a flow greater than the median could reduce their flows by either reducing the amount of water per battery directly, or using efficient methods described in Section VII.

Truck Wash. Sampling and industry survey data support a discharge allowance for truck wash wastewater in both the battery manufacturing and nonferrous metals manufacturing categories. EPA observed that trucks are used to transport used batteries in connection with battery cracking (secondary lead subcategory of the nonferrous metals manufacturing category) processes. Trucks are also used to transport batteries for various purposes related to battery manufacturing operations. The truck wash regulatory flow for the lead subcategory of battery manufacturing applies only to those sites without an associated on-site secondary lead smelting plant. Truck washing at sites that have battery cracking or secondary lead smelting will be regulated under the nonferrous metals manufacturing regulation. Equivalent regulatory flows for truck wash are promulgated under the two regulations.

Flow data to calculate the BPT flow for battery manufacturing truck wash operations were obtained from two sampling visits after proposal. For each site, a daily truck wash flow was calculated using the highest measured flow per truck (150 liters) from the two sites measured. Assuming 250 operating days per year, these flows were converted to annual flows. Production data from 1982 was used for both plants to obtain two production normalized flows which were then averaged to obtain the BPT flow of 0.014 l/kg of batteries trucked.

Laundry. Eleven sites in the subcategory reported on-site laundering of work clothing based on industry survey data. Flow data were obtained during 2 sampling visits for 2 laundry operations. Both of these plants reported discharge of laundry wastewater. Although information of laundry activities indicates that most plants do not have on-site laundries, those plants which do will have a discharge of laundry wastewater; therefore, a BPT regulatory flow for on-site laundering of work uniforms is appropriate. Laundry discharge flows were normalized by work uniform using measured flow rates obtained at both sites. These flows were averaged to obtain 21.4 liters per uniform. The number of uniforms washed per day at each plant reporting this element was obtained from the industry survey. Using the average liters per uniform, number of uniforms per day, and an assumed 250 days per year, an annual flow from the laundry operation was estimated for each of the 11 plants. The total laundry flow from all eleven plants was divided by the total of their respective annual production values (the most recently available data) to determine the BPT regulatory flow of 0.109 l/kg.

<u>Miscellaneous</u>. A BPT regulatory flow of 0.427 l/kg has been established to cover a miscellaneous group of wastestreams. These wastestreams are associated with the following process elements: floor wash, wet air pollution control, battery repair, laboratories, hand wash, and respirator wash. Discharge allowances for these six streams are combined together because all of those activities occur at almost all lead plants, and combining them into a single group, facilitates administration. If a plant has any one of these streams, then the plant receives the entire miscellaneous wastewater discharge allowance. The miscellaneous regulatory flow is the arithmetic sum of the regulatory flows established for each process element of the miscellaneous group. Each individual process element and its associated regulatory flow is discussed below.

Floor Wash - Information provided in the dcp, industry survey responses, and from site visits were considered in establishing the regulatory flow for floor wash. Data were available from 13 plants, of which two reported zero discharge. A variety of cleaning methods are used including buckets, mops, hoses, and other manual methods, as well as wet power (vacuum) floor scrubbers. A normalized flow of 0.13 l/kg has been calculated based on the median of production normalized flow data reported and measured. This regulatory flow applies to floor wash outside of the pasting area.

Wet Air Pollution Control - The established regulatory flow for wet air pollution control scrubber blowdown is based on model technologies typical of those used for wet scrubbing of pasting areas and wet scrubbing of formation areas (See Sections V and VII). These models incorporate data obtained from on-site plant visits and vendor information for the two scrubber types typically used. Observations made during plant visits indicated that most plants have no more than two wet scrubber operations on-site; therefore, a regulatory flow which sums both wet scrubber model flows has been established. The BPT regulatory flow is based on the sum of two model technology flows instead of the average normalized flow shown in Table V-3. As discussed in Section V, a wide range of discharge flows were reported from wet air pollution control activities even though only two different scrubbers designs are used in this subcategory. The two model technologies accurately reflect the discharge flows which can be achieved from the two types of wet air pollution control devices used in this subcategory.

The information reported in the battery manufacturing and casting dcp, site visits, plant contacts, and vendor contacts were used to identify the types of scrubbers used at lead subcategory plants. As discussed in Section V, these were identified as two design types which are used in two groups of process elements: group I consists of leady oxide production, pasting, grid manufacture and assembly, and group II consists of the formation elements. Each design has a characteristic discharge mode of operation and flow rate. The group I design incurs infrequent (semi-annual) batch dumping provided that proper corrosion protection measures are taken, such as the addition of alkali into the holding tank. The type of discharge mode is supported by plant visits and dcp flow data. The actual flow used for the group I model was obtained from equipment vendor information for a conservatively large scrubber: accomodates 50,000 SCFM with a water capacity of 3,000 gallons. (Typically reported sizes in group I accommodate 6-14,000 SCFM with a capacity of 220-1330 gallons.) This volume (3000 gallons) is assumed to be dumped semi-annually. Pasting area scrubbing represents the most common group I scrubbing activity. The BPT regulatory flow for group I scrubbing was calculated by multiplying the annual model discharge volume by the number of sites reporting pasting area scrubbers and dividing by the total production from these sites. A 0.005 l/kg normalized flow was obtained using this procedure.

In a similar manner to the approach used to obtain a normalized flow for group I scrubbers, a group II scrubber normalized flow was obtained. One of the sampled plants was used as a model for the scrubber design and operating mode. Equipment was added (in the model) to accommodate recycle of the existing model plant washdown water as well as for caustic addition to allow for more extensive recycle. A vendor-recommended blowdown rate was used (1.5 x (0.005 gpm per 1000 cfm of air)). This factor was multiplied by the flow rate of air through each scrubber in the model plant and then multiplied by the number of scrubbers used at the model plant. This resulting flow was then converted to an annual flow based on the operation of the model plant system.

The normalized flow for formation scrubbing was calculated for the model plant using the 1982 production for the model plant. This normalized flow is 0.006 l/kg.

The complete wet scrubber regulatory flow of 0.011 l/kg was calculated by adding group I and group II normalized flows.

Battery Repair - Thirty plants which returned industry survey information indicated some type of battery repair operation. However, flow data is available from only three plants from which a normalized flow can be calculated. The BPT regulatory flow has been established at the median flow of 0.25 l/kg. Contributing wastewater sources include dumped electrolyte, repair area washdown, and contact cooling water.

Laboratory - Site visit data were used to determine a regulatory flow for wastewater discharged from on-site laboratory facilities. The laboratory tests performed at the battery plants which generate wastewater were found to be very similar from plant to plant; there were no differences which justified significant flow differences between plants. Observations made indicated that some plants reclaim quality control lead samples taken for their lead value. Based on this practice, lead loadings in the discharge water to treatment should mostly be due to lab instrument washing, dumped electrolyte from battery teardown and wet air pollution control scrubbers used to control fumes from various tests; also some tests require plate rinsing before chemical assay. These wastewater sources are included in the process water flow for the laboratory process element. Other flows such as noncontact cooling water for graphite furnaces and other instrumentation are not included.

Discharge information was obtained for all sites visited, and flow data were obtained from five sites; two were measured and three flows were plant-reported. Data from four of these sites were used in the normalized flow calculation; one value was more than an order of magnitude above the others without any associated justification. The normalized flow was calculated by adding the daily flows from the four sites, converting the total daily flow to an annual flow assuming 250 days of operation per year, and dividing the total annual flow by the total production from the four sites. A normalized flow of 0.003 l/kg was calculated from the above procedure.

Hand Wash - Data were collected from site visits and industry surveys on hand wash operations; these data support a regulatory flow for employee hand wash within the production areas of the plant. Hand wash is assumed to be practiced at all sites. Of the sites visited, most discharge hand wash water to a sanitary sewer without treatment while a few sites treat hand wash water before discharge. Hand wash flows were measured at two sites yielding the same flow values (1.5 l/person). This flow (1.5 l/person) was used to obtain individual site flow rates by using the number of employees in required washup at the site. The number of employees were reported in the industry survey responses. This daily flow for each site was converted to an annual flow using 250 days per year. The 63 annual flows were added and divided by the 63 plants' associated total production. A normalized flow of 0.027 l/kg of total lead used was established for hand wash.

Respirator Wash - Sampling data and industry survey data were used to determine a normalized flow of 0.006 l/kg for respirator wash water. Fifty-one plants reported on-site respirator wash activities. Flow data were available for six plants, all of which reported the discharge of this wastewater. Flow values from the six plants were normalized by the number of respirators washed and averaged to obtain an average flow of 4.6 liters per respirator washed. For those sites reporting the number of respirators washed per day in the industry survey responses, the average flow per respirator was used to determine a daily flow at each site. These daily flows were added and the sum was converted to an annual flow assuming 250 operating days per year. The total annual flow was then divided by the sum of the respective productions to obtain the regulatory flow. The most updated production values were used.

MODEL TREATMENT TECHNOLOGY

BPT end-of-pipe technology for the lead subcategory is illustrated in Figure IX-1 (page 583). The BPT treatment scheme consists of oil and grease removal by oil skimming, and end-of-pipe lime and settle treatment applied to all combined wastewater. The end-of-pipe model technology of lime and settle treatment is intended to be state of the art lime and settle technology which is properly designed and carefully operated. Caustic, sodium carbonate, or lime is added to adjust the pH to a level that promotes adequate precipitation. The optimum pH range for precipitation of metals, especially lead, from lead subcategory waste streams is 8.8-9.3. Carbonate ion in addition to hydroxide may be required to promote the effective precipitation of lead. Carbonate precipitation is similar to hydroxide precipitation in terms of metals removal, and the treated effluent from carbonate precipitation is compatible for use in lead recovery processes. Alternatively, treatment system performance can be improved by evaluating other precipitation technologies. Sulfide precipitation is more effective than hydroxide precipitation at removing lead because of the lower solubility of lead sulfide. Also, iron coprecipitation, which involves the addition of iron salts to a precipitation and settling system, can enhance the removal efficiency of the system. However, since the presence of iron salts in recycled waters could be detrimental to lead subcategory processes, the use of iron coprecipitaton would most likely be limited to the treatment of waste streams which are to be discharged. Proper pH control will enhance the settling of both metal precipitates and suspended solids. Clarifiers can achieve required effluent concentrations; however, comparable effluent concentrations can be achieved in tanks or lagoons or by filtration. In some cases, provisions of an oil skimmer may also be required to achieve acceptable effluent quality.

The sludge which accumulates during settling must be removed to ensure continued effective operation of the settling device. A vacuum filter is included 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, and the sludge should be sent to metal recovery or to a secure landfill. It is not anticipated that such sludges will be hazardous wastes.

Lime and settle (chemical precipitation) technology was considered as BPT following a careful review of collected information characterizing process wastewater, present treatment practices, and present manufacturing practice. Removal of metals, the primary requirement in treating lead subcategory process wastewater, can be achieved by chemical precipitation and settling. This technology is similar to that presently in-place at plants which treat their wastewaters. As summarized in Table IX-3 (page 561) the most frequently reported end-of-pipe systems in this subcategory were equivalent to pH adjustment and settling or pH adjustment and filtration (53 plants); ten others reported the use of filtration following pH adjustment and settling. pH adjustment only or no pH adjustment with treatment was practiced at 46 plants, and 74 plants reported no treatment in-place.

On the basis of 33 plant visits and an evaluation of effluent data submitted, which was discussed in Section V, it was concluded that existing treatment facilities in the subcategory generally were improperly designed, maintained, or operated. In fact, those plants which had filtration units in place, used them generally as primary solids removal units and not as polishing filters designed to achieve low effluent pollutant concentrations. Based on the observation that most plants already have BPT end-of-pipe systems in-place, the selected BPT is judged to be reasonable. A discussion of the reasonableness of the BPT limitations is presented later in this section. As an alternative to reducing effluent concentrations to meet discharge limitations, the discharge flow can be reduced by either substitution of dry processes or by the reuse of treated or untreated wastewater.

EFFLUENT LIMITATIONS

The pollutant mass discharge limitations (milligrams of pollutant per kilogram of pnp) were calculated by multiplying the BPT regulatory flows summarized in Table IX-1 (l/kg) by the concentration achievable by the BPT model treatment system summarized in Table VII-21 (mg/l) for each pollutant parameter considered for regulation at BPT (l/kg x mg/l = mg/kg). The results of this computation for all process elements and regulated pollutants in the lead subcategory are summarized in Tables IX-4 to IX-16 (pages 562 to 574). These limitation tables list all the pollutants which were considered for regulation and those specifically regulated are marked with an asterisk.

POLLUTANT REMOVALS AND COSTS

In the establishment of BPT, the cost of application of technology must be considered in relation to the effluent reduction benefits from such application. The quantity of pollutant removal by BPT is displayed in Table X-6 (page 604) for the total subcategory and Table X-7 (page 605) for direct dischargers only. Treatment costs are shown in Table X-8 (page 606). The capital cost of BPT as an increment above the cost of in-place treatment equipment is estimated to be $8.60 million ($1983) ($0.715 million for direct dischargers) for the lead subcategory. Annual costs of BPT for the lead subcategory are estimated to be $5.13 million ($1983) ($0.499 million for direct dischargers). The quantity of pollutants removed from estimated raw waste by the BPT model technology for this subcategory is estimated to be 10,978,344 kg/yr (791,232 kg/yr for direct dischargers) including 1,601,278 kg/yr (115,407 kg/yr for direct dischargers) of toxic metals. The pollutant removals justify the costs incurred by the plants in the lead subcategory.

REASONABLENESS OF THE LIMITATIONS

To confirm the reasonableness of these limitations for this subcategory, limitations were compared to actual performance at lead subcategory plants by first looking at plant flows. Because BPT is common end-of-pipe treatment from multiple process elements, and because compliance with the regulation will be judged on a total plant basis, total plant performance is compared rather than performance from each process element. This was accomplished by calculating total process wastewater BPT regulatory flow rates for each plant in the subcategory based on available production information and on the normalized process element BPT flows shown in Table IX-1. These calculated BPT flow rates were then compared to effluent flow rates actually reported or measured. Effluent concentrations were also compared to those attainable by lime and settle (L&S) technology as presented in Table VII-21. Finally total plant pollutant mass discharges were compared to BPT limitations for plants which, on the basis of effluent flow rates and concentrations, were potentially meeting BPT mass discharge limitations.

As a first step in this comparison, lead subcategory process wastewater flow rates from each plant were compared to the flow rates upon which mass limitations for the plant would be based. Since operating schedules are generally regular in this subcategory, this comparison was made on the basis of hourly flows. To calculate actual process wastewater discharge flows, the discharge flow rate (l/hr) from each process element at the plant were added. The total process wastewater flow from this procedure represents the sum of reported process element flows from the plant. Process elements for which flow data were not reported are not included in the total flow. In general, flow data from the ancillary streams added after proposal (laboratory, truck wash, handwash, respirator wash, and laundry) are not included in the total reported process element flows, since flow data was only available from a few plants for these process elements. (Flows from these process elements are included when available.) At some plants, individual process element flows were either not available, or only available for a few of the process elements that the plant reported. However, most of these plants reported a total process wastewater flow in their dcps. For these plants, the total process wastewater flow was assumed to be equal to the combined flow from process elements reported in the dcp. It was assumed that discharges from process elements not reported in the dcps (such as laboratory, truck wash, handwash, respirator wash, and laundry) were not included in the total process wastewater flow. For all plants, the total process wastewater flow was compared to the sum of corresponding BPT flows for each process element included in the total flow. Production information was used to determine the hourly BPT process element flows. The annual pnp was divided by the plants operating time to determine an hourly pnp. This hourly pnp was multiplied by the normalized flow shown for the process element in Table IX-1. The hourly BPT process element flows were then added to determine the total BPT flow. This BPT flow was then compared to the total process wastewater flow. Table IX-17 (page 575) presents a comparison of these flows.

Fifty-seven plants reported zero discharge of process wastewater from the lead subcategory and were, therefore, complying with the BPT flow and limitations. Twenty-eight additional plants were identified that produce total wastewater discharge flows less than those used in calculating BPT mass discharge limitations. Fourteen of the twenty-eight have BPT treatment systems (L&S technology) in-place, and 13 of these 14 submitted effluent data which is summarized in Table IX-18 (page 580). Plants which had pH adjustment and filtration were considered to have treatment equipment in-place that is equivalent to BPT (lime and settle). However, the filtration systems were usually used only for primary solids removal. Only one plant submitted data indicating that it would comply with the average lead concentration values shown in Table VII-21; however, its TSS concentration was significantly high, indicating a poorly maintained settling system. On the basis of the data submitted, operational factors which influence treatment performance could only be evaluated for the plants submitting pH data. As discussed in Section VII, pH should be maintained at 8.8-9.3 for the most efficient removal of pollutants. Only one plant (Plant J) reported a pH which was in the 8.8-9.3 range. However, this plant has other operational problems (these problems are discussed later) which result in a high effluent lead concentration.

Lead subcategory treated wastewater values (pH, lead and TSS) vary considerably among plants indicating that treatment systems vary in design and operating practices. This was also evident at plants that were sampled. Six of the sampled plants discharge process wastewater and have BPT equivalent treatment sytems in-place. Sampling data from these six plants are also summarized in Table IX-17. Three of the six plants (Plants A, J and M) were maintaining flows in compliance with BPT, and three (Plants N, O, and P) were not. As shown in Table IX-17, plant A was not maintaining pH within an acceptable range, and consequently was not meeting lead concentrations for BPT technology. The filtration system at this plant was used as a primary solids removal device and was not operating effectively at the time of sampling, resulting in high TSS concentrations. Sampling data at this plant did not support the plant's dcp data for lead concentration and showed that the plant was not complying with its permit which allowed a maximum of 1.0 mg/l of lead to be discharged. With proper pH control and the addition of settling tanks with adequate retention time, this plant would be expected to comply with its permit and BPT limitations. Plant J not only had the same operational problems as plant A (improper pH control and no settling with filtration), but also the treatment system was being overloaded to almost triple its design capacity, due to increased production. This plant could readily comply with BPT limitations by maintaining proper pH control and by either limiting flows to the treatment system to design levels only, or enlarging the treatment system. The industry survey data from Plant J was submitted after the plant was sampled. These data indicate that the plant now operates at an average pH level of 9. However, the effluent lead concentration reported in the industry survey indicates that the plant has not solved its other operational problems. It was observed during the visit to Plant M that a pH of 7.5 was used to precipitate metals. This is well below the effective removal range of 8.8 to 9.3. Despite this low pH, lead was not detected in the effluent from this plant during sampling. Industry survey data from Plant M (which represents wastewater treatment performance over a longer time period than sampling) indicate that an average effluent lead concentration of 0.25 mg/l is achieved. Thus, it appears that Plant M does not achieve the effluent lead concentrations achieved during sampling on a regular basis. This is probably due to the low operating pH. If the operating pH is maintained within the 8.8 to 9.3 range, this plant would be expected to achieve effluent concentrations similar to those achieved during sampling on a regular basis.

Three of the sampled plants with BPT equivalent treatment systems in-place do not comply with the BPT flows. Two of these plants (Plants N and O) maintain pH within the effective removal range. This enables these two plants to achieve effluent lead concentrations comparable to the average lead concentration shown in Table VII-21. Several operational problems were observed at Plant P. Plant P uses a clarifier with tube settlers to remove precipitated solids. As with Plant M, an operating pH of 7.5 was observed to be used to precipitate metals. In addition, the tube settler used for primary solids removal was observed to be laden with solids. This impedes the manner in which the tube settler removes solids. Also, the clarifier at this plant is designed for continuous operation, but was operated intermittantly during the visit. A lead concentration of 0.100 mg/l was observed in the effluent lead sample taken during the visit to this plant. As shown by the industry survey data from Plant P, this concentration is not achieved on a regular basis. If the operational problems of the wastewater treatment system are corrected, this plant would be expected to achieve the concentrations observed during sampling on a regular basis.

Other lead plants which were visited, but not sampled supported the conclusions reached from evaluation of submitted data and sampling data. Several plants were maintaining the BPT process flows and also had BPT or better end-of-pipe treatment systems in-place which allowed the plants to reuse the water and thus achieve zero discharge of wastewater pollutants. Other plants appeared to have the same operational problems (no pH control and overloaded treatment systems) as some of the sampled plants previously mentioned. Four additional plants in the lead subcategory were sampled. Three of these plants achieve zero discharge of wastewater pollutants by methods other than BPT technology such as treated wastewater reuse, contract hauling and evaporation, or land application. Process wastewater was sampled at each of these three plants and sampling results are shown in Section V. The effluent from wastewater treatment (which is reused or land applied) at one of these plants was also sampled. Sampling results and an evaluation of the plants' treatment system are presented in Section V. The other sampled plant uses a lime, settle, and filter wastewater treatment system. This system was characterized during sampling and is discussed in Section V.

In summary, the above discussion shows that 85 plants currently comply with BPT flows, and that of the 112 plants with treatment in-place, the most common treatment system was based on lime and settle technology. Most plants did not indicate the presence of ancillary streams added after proposal. If these streams are assumed to be present in the total process flow from these plants and the added flow allowance added, two additional plants would meet the BPT flows. When EPA evaluated treatment system performance at plants with BPT treatment and BPT flow, the data indicated that treatment system design and operating practices at most plants were inadequate. In particular, close pH control was not practiced at BPT lead subcategory plants. Because lime and settle treatment practices in the lead subcategory are generally inadequate the effectiveness of lime and settle technology must be transferred from other industrial categories with similar wastewaters. From the data and information collected, it appears that most lead subcategory plants can comply with BPT with only minimal changes in their present practices, such as wastewater flow control, pH control, and better control of operating parameters. Therefore, the selected BPT level has been determined to be reasonable.

APPLICATION OF REGULATIONS IN PERMITS

The purpose of these limitations (and standards) is to form a uniform national basis for regulating wastewater effluent from the battery manufacturing category. For direct dischargers, the regulations are implemented through NPDES permits. Because of the many elements found in lead battery manufacturing and the apparent complexity of the regulation, an example of applying these limitations to determine the allowable discharge from battery manufacturing is included. The lead subcategory battery manufacturing category is regulated on an individual wastestream "building block" approach as shown below.

Example A. Plant X manufactures lead acid batteries using 5.2 x 10^6 kg lead/yr. The plant operates for 250 days during the year. Leady oxide is purchased; paste is mixed in the plant and applied to casted grids; plates are cured in stacks; 80% of the batteries are charged using closed, single-fill formation; 20% are formed using open formation and dehydration for dehydrated batteries; all batteries are detergent washed. The plant provides hand wash for their employees, routinely washes floors in process areas, and has respirator wash.

Table IX-19 (page 582) illustrates the calculation of allowable daily discharge of lead for this plant.

TABLE IX-1

FLOW BASIS FOR BPT MASS DISCHARGE LIMITATIONS
LEAD SUBCATEGORY

Process Element	Median Flow (l/kg)	Mean Flow (l/kg)	BPT Flow (l/kg)
<u>Anodes and Cathodes</u>			
Leady Oxide Production	0.00	0.37	0.00
Grid Manufacture			
Mold Release Formulation	*	0.006	0.006
Direct Chill Casting	0.0002	0.0002	0.0002
Lead Rolling	0.006	0.006	0.006
Paste Preparation and Application	0.00	0.49	0.00
Curing	0.00	0.03	0.00
Closed Formation (in case)			
Single Fill	0.00	0.28	0.00
Double Fill	0.45[1/]	0.92	0.45
Fill and Dump	0.45[1/]	1.83	0.45
Open Formation (out of case)			
Dehydrated	11.05	28.26	11.05
Wet	0.00	0.36	0.053[2/]
Plate Soak	0.021	0.026	0.021
<u>Ancillary Operations</u>			
Battery Wash			
Detergent	0.90	1.70	0.90
Water Only	0.59	3.47	0.59

TABLE IX-1 (continued)

FLOW BASIS FOR BPT MASS DISCHARGE LIMITATIONS
LEAD SUBCATEGORY

Process Element	Median Flow (l/kg)	Mean Flow (l/kg)	BPT Flow (l/kg)
Anodes and Cathodes			
Truck Wash	0.014	0.014	0.014
Laundry	*	0.109	0.109
Miscellaneous Group			
Floor Wash	0.13	0.11	0.13
Wet Air Pollution Control	0.00	0.26	0.011[3]
Battery Repair	0.25	0.20	0.25
Laboratory	*	0.003	0.003
Hand Wash	*	0.027	0.027
Respirator Wash	*	0.006	0.006
-Total Miscellaneous Group			0.427

[1] Based on combined data for double fill and fill and dump formation.

[2] Based on subset of plants which discharge open wet formation wastewater

[3] Based on sum of model flows for pasting and formation area scrubbers.

*Calculated as a flow weighted average - no median available

TABLE IX-2

SUMMARY OF ZERO DISCHARGE FOR LEAD SUBCATEGORY PROCESS ELEMENTS

Process Element	No. of Plants Reporting Flow Data For Process Element	No. of Plants Reporting Zero Discharge in Process Element	Method of Attaining Zero Discharge
Leady Oxide Production	41	29	Use of non-contact cooling water on ball mills.
Grid Manufacture			
Mold Release Formulation	2(29)	0	Use commercially available mold-release formulations.
Direct Chill Casting	1(5)[1/]	0	None reported.
Lead Rolling	1(5)[1/]	5	Contract hauling.
Paste Preparation and Application	100	57	Recycle of wastewater after settling (common practice).
Curing	97	87	Curing in covered stacks; in humidity controlled rooms; internal recirculation.
Closed Formation--			
Single Fill	43	31	Low rate and controlled formation and reuse battery case rinsewater in acid cutting.
Double Fill	35	7	Low rate and controlled formation and reuse battery case rinsewater in acid cutting.
Fill and Dump	13	1	Low rate and controlled formation and reuse battery case rinsewater in acid cutting.
Open Formation--			
Dehydrated	42	2	Water recycled after treatment.
Wet	16	10	Reuse formation acid.
Plate Soak	3	0	Reuse plate soak acid.

TABLE IX-2 (continued)

SUMMARY OF ZERO DISCHARGE FOR LEAD SUBCATEGORY PROCESS ELEMENTS

Process Element	No. of Plants Reporting Flow Data For Process Element	No. of Plants Reporting Zero Discharge in Process Element	Method of Attaining Zero Discharge
Battery Wash			
Detergent	22	0	Reuse battery case rinsewater in acid cutting.
Water Only	44	1	Reuse battery case rinsewater in acid cutting.
Truck Wash	2 (18)[1]	0	None reported.
Laundry	2 (11)[1]	0	Use offsite commercial services.
Floor Wash	13	2	Use of dry floor cleaning procedures.
Wet Air Pollution Control[2]	56 (80)	32	Use of dry baghouses; reuse group I scrubber water in paste washdown; eliminate overflow from group I scrubbers; no washdown of demister mesh in formation scrubbers.
Battery Repair	3	0	None reported.
Laboratory	4 (57)[1]	0	None reported.
Hand Wash	2 (63)[1]	0	None reported.
Respirator Wash	6 (51)[1]	0	Reclaim disposable respirators at a smelter.

[1] The number in parenthesis is the number of plants which reported being active for these process elements.

[2] Based on number of scrubbers from all process areas but laboratory. The number in parenthesis is number of plants reporting scrubber usage.

TABLE IX-3

SUMMARY OF TREATMENT IN-PLACE AT LEAD SUBCATEGORY PLANTS

Treatment In-Place	Number of Plants	Discharge Status		
		Direct	Indirect	Zero
None	74	1	12	42 1/
Less than BPT (pH adjust only or no pH adjust with treatment)	46	1 (1)	40 (9)	5 (1)
BPT Treatment (L&S, or pH adjust, filter)	53	8 (2)	40 (5)	5
BAT Treatment (L,S & F)	10	2 (1)	7	1
Not Classified	3	0	0	3

1/ Discharge status is unknown for 19 plants, which are included in the total number of plants with no treatment, but not under discharge status. Fifteen of these plants are not full line manufacturers. Based on the observations that most non-full line manufacturers are zero dischargers, and that permit information was not found on these plants, they are considered as indirect or zero dischargers with no reported treatment in-place.

( ) Indicates number of plants that are closed.

TABLE IX-4

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Mold Release Formulation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.01	0.008
Cadmium	0.002	0.0009
Chromium	0.003	0.001
*Copper	0.011	0.006
*Lead	0.002	0.001
Mercury	0.002	0.0006
Nickel	0.01	0.0076
Silver	0.0025	0.001
Zinc	0.009	0.004
Aluminum	0.04	0.02
*Iron	0.007	0.004
Manganese	0.004	0.002
*Oil and Grease	0.120	0.072
*TSS	0.246	0.117
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-5

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Direct Chill Lead Casting

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.00057	0.00026
Cadmium	0.00007	0.00003
Chromium	0.000088	0.000036
*Copper	0.0004	0.0002
*Lead	0.00008	0.00004
Mercury	0.00005	0.00002
Nickel	0.00038	0.00025
Silver	0.000082	0.000034
Zinc	0.00029	0.00012
Aluminum	0.0013	0.0006
*Iron	0.0002	0.0001
Manganese	0.0001	0.00006
*Oil and Grease	0.004	0.002
*TSS	0.008	0.003
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-6

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Lead Rolling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.017	0.008
Cadmium	0.002	0.0009
Chromium	0.003	0.001
*Copper	0.011	0.006
*Lead	0.003	0.001
Mercury	0.002	0.0006
Nickel	0.012	0.008
Silver	0.002	0.001
Zinc	0.009	0.004
Aluminum	0.039	0.019
*Iron	0.007	0.004
Manganese	0.004	0.002
*Oil and Grease	0.120	0.072
*TSS	0.246	0.117
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-7

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Lead Rolling

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead rolled English Units - lb/1,000,000 lb of lead rolled	
Antimony	0.07	0.03
Cadmium	0.008	0.004
Chromium	0.01	0.004
*Copper	0.04	0.02
*Lead	0.01	0.005
Mercury	0.006	0.002
Nickel	0.04	0.03
Silver	0.01	0.004
Zinc	0.03	0.01
Aluminum	0.15	0.07
*Iron	0.03	0.01
Manganese	0.02	0.007
*Oil and Grease	0.47	0.28
*TSS	0.96	0.45
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-8

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Closed Formation - Double Fill, or Fill & Dump

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	1.29	0.58
Cadmium	0.15	0.07
Chromium	0.20	0.08
*Copper	0.86	0.45
*Lead	0.19	0.09
Mercury	0.11	0.05
Nickel	0.86	0.57
Silver	0.18	0.08
Zinc	0.66	0.27
Aluminum	2.89	1.44
*Iron	0.54	0.27
Manganese	0.31	0.13
*Oil and Grease	9.00	5.40
*TSS	18.45	8.78
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-9

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Open Formation - Dehydrated

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	31.71	14.14
Cadmium	3.75	1.65
Chromium	4.86	1.98
*Copper	20.99	11.05
*Lead	4.64	2.21
Mercury	2.76	1.10
Nickel	21.21	14.03
Silver	4.53	1.87
Zinc	16.13	6.74
Aluminum	71.05	35.36
*Iron	13.26	6.74
Manganese	7.51	3.20
*Oil and Grease	221.00	132.60
*TSS	453.05	215.47
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-10

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Open Formation - Wet

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.15	0.07
Cadmium	0.02	0.007
Chromium	0.02	0.009
*Copper	0.10	0.05
*Lead	0.02	0.01
Mercury	0.01	0.005
Nickel	0.10	0.07
Silver	0.02	0.009
Zinc	0.08	0.03
Aluminum	0.34	0.17
*Iron	0.06	0.03
Manganese	0.04	0.02
*Oil and Grease	1.06	0.64
*TSS	2.17	1.03
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-11

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Plate Soak

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.06	0.03
Cadmium	0.007	0.003
Chromium	0.009	0.003
*Copper	0.04	0.02
*Lead	0.009	0.004
Mercury	0.005	0.002
Nickel	0.04	0.03
Silver	0.008	0.003
Zinc	0.03	0.01
Aluminum	0.14	0.07
*Iron	0.03	0.01
Manganese	0.01	0.01
*Oil and Grease	0.42	0.25
*TSS	0.86	0.41
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-12

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Battery Wash (Detergent)

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	2.58	1.15
Cadmium	0.31	0.14
Chromium	0.396	0.162
*Copper	1.71	0.90
*Lead	0.38	0.18
Mercury	0.23	0.09
Nickel	1.73	1.14
Silver	0.37	0.15
Zinc	1.31	0.55
Aluminum	5.79	2.88
*Iron	1.08	0.55
Manganese	0.61	0.26
*Oil and Grease	18.00	10.80
*TSS	36.90	17.55
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-13

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Battery Wash (Water Only)

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	1.69	0.76
Cadmium	0.20	0.09
Chromium	0.26	0.11
*Copper	1.12	0.59
*Lead	0.25	0.12
Mercury	0.15	0.06
Nickel	1.13	0.75
Silver	0.24	0.10
Zinc	0.86	0.36
Aluminum	3.79	1.89
*Iron	0.71	0.36
Manganese	0.40	0.17
*Oil and Grease	11.80	7.08
*TSS	24.19	11.51
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-14

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Truck Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Antimony	0.040	0.017
Cadmium	0.004	0.002
Chromium	0.006	0.002
*Copper	0.026	0.014
*Lead	0.005	0.002
Mercury	0.003	0.001
Nickel	0.026	0.017
Silver	0.005	0.002
Zinc	0.020	0.008
Aluminum	0.09	0.04
*Iron	0.016	0.008
Manganese	0.01	0.004
*Oil and Grease	0.280	0.168
*TSS	0.574	0.273
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-15

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Laundry

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.31	0.14
Cadmium	0.037	0.016
Chromium	0.05	0.02
*Copper	0.21	0.11
*Lead	0.05	0.02
Mercury	0.027	0.011
Nickel	0.209	0.138
Silver	0.045	0.019
Zinc	0.16	0.07
Aluminum	0.70	0.35
*Iron	0.13	0.07
Manganese	0.07	0.03
*Oil and Grease	2.18	1.31
*TSS	4.47	2.13
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-16

LEAD SUBCATEGORY
BPT EFFLUENT LIMITATIONS

Miscellaneous Wastewater Streams

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	1.23	0.55
Cadmium	0.15	0.06
Chromium	0.19	0.08
*Copper	0.81	0.43
*Lead	0.18	0.09
Mercury	0.11	0.04
Nickel	0.82	0.54
Silver	0.18	0.07
Zinc	0.62	0.26
Aluminum	2.75	1.37
*Iron	0.51	0.26
Manganese	0.29	0.12
*Oil and Grease	8.54	5.12
*TSS	17.51	8.33
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE IX-17

COMPARISON OF ACTUAL TOTAL FLOW RATES TO BPT HOURLY FLOW RATES

Plant ID	Actual Flow Meets BPT	Actual Flow (l/hr)	BPT Hourly Flow (l/hr)
107	x	1503	11475
110		NA	NA
112		3108	621
122		11706	5091
132		NA	NA
133		NA	NA
135	x	0	NA
138		NA	NA
144	x	0	2650
146		6815	4000
147	x	0	6.0
152		9280	6850
155		NA	NA
158	x	0	NA
170	x	0	NA
173	x	0	0
178	x	0	2143
179	x	7.57	20
182		NA	NA
184	x	0	1632
190	x	0	NA
191		37325	105
198		10266	591
207		18851	5685
208		NA	NA
212		7041	2966
213		454	0
226	x	9312	13200
233		9375	8070
237	x	11129	16775
239		6106	2255
242		NA	NA
255		NA	NA
261		2271	1019
269	x	12212	20615
277		NA	96
278		5770	5.1
280		NA	NA
288		NA	NA
295	x	0	NA

TABLE IX-17 (Continued)

COMPARISON OF ACTUAL TOTAL FLOW RATES TO BPT HOURLY FLOW RATES

Plant ID	Actual Flow Meets BPT	Actual Flow (l/hr)	BPT Hourly Flow (l/hr)
299	x	0	NA
311		20895	13496
320		34450	17065
321	x	0	NA
331		2498	2200
342		61920	31635
346	x	0	NA
349	x	7845	16150
350		NA	NA
356	x	0	NA
358		7041	3643
361		NA	NA
366	x	0	NA
370		NA	NA
371	x	3390	7385
372	x	0	NA
374		3861	0
377	x	0	NA
382	x	1197	3160
386	x	7950	10083
387	x	2006	2825
400		3835	1949
402		NA	NA
403		NA	NA
406		NA	NA
421	x	0	1.3
429	x	0	NA
430	x	0	0
436	x	0	0
439		29000	4107
444	x	0	NA
446	x	2063	4015
448		14645	3525
450		27252	8190
462	x	2574	2614
463		NA	NA
466	x	0	330
467	x	0	NA
469	x	15	1350
472	x	0	1900

TABLE IX-17 (Continued)

COMPARISON OF ACTUAL TOTAL FLOW RATES TO BPT HOURLY FLOW RATES

Plant ID	Actual Flow Meets BPT	Actual Flow (l/hr)	BPT Hourly Flow (l/hr)
480		30610	19680
486		NA	NA
491		NA	NA
493		NA	605
494	x	3110	3735
495	x	0	NA
501		12624	4620
503	x	0	35185
504	x	0	NA
513	x	1363	3895
517	x	0	NA
520		4542	1205
521	x	0	NA
522	x	0	NA
526		18170	2563
529	x	570	700
536		NA	NA
543	x	0	23
549		47470	645
553		3449	1318
572		2275	1196
575		3634	2000
594	x	0	NA
620		NA	NA
623		NA	480
634		1590	1535
635	x	1685	4915
640		25196	16648
646	x	476	555
652		12705	2080
656		NA	NA
668	x	0	0
672		52950	9908
677	x	0	NA
680		1534	1105
681		4542	492
682		6814	3925
683	x	0	NA
685		6359	4230
686		8404	3960
690	x	0	815

TABLE IX-17 (Continued)

COMPARISON OF ACTUAL TOTAL FLOW RATES TO BPT HOURLY FLOW RATES

Plant ID	Actual Flow Meets BPT	Actual Flow (l/hr)	BPT Hourly Flow (l/hr)
704		27125	3260
705		3180	2115
706	x	0	0
708		NA	3635
714	x	1590	2025
716		NA	200
717		6490	4350
721	x	0	1265
722		NA	NA
725	x	0	NA
730	x	443	2184
731		2858	974
732		3607	2230
733		NA	NA
738		29080	24815
740		NA	NA
746	x	0	NA
765		11690	10051
768	x	7881	11205
771		1363	NA
772		11500	30
775		4088	2895
777		4325	2785
781		NA	NA
785		41660	10190
786		5120	1790
790	x	0	0
796	x	0	NA
811		NA	NA
814		13130	2830
815		598	141
817	x	0	0
820	x	3407	3900
828	x	40	90
832		10520	7281
844		NA	1810
852		16070	15055
854	x	0	NA
857	x	0	4730
863		11055	6350
866	x	0	NA

TABLE IX-17 (Continued)

COMPARISON OF ACTUAL TOTAL FLOW RATES TO BPT HOURLY FLOW RATES

Plant ID	Actual Flow Meets BPT	Actual Flow (l/hr)	BPT Hourly Flow (l/hr)
877		46165	4615
880	x	0	NA
883	x	0	100
893	x	2470	2865
901	x	0	580
917		18851	11785
920		NA	NA
927	x	0	NA
936		3706	2750
939		NA	NA
942	x	0	NA
943	x	17261	26595
947		18397	16094
951		1135	NA
963	x	0	0
964	x	0	NA
968	x	0	NA
971	x	0	5026
972		23837	4520
976	x	26801	33845
978	x	1840	7199
982	x	10540	12340
979	x	0	0
990		3180	2389

TABLE IX-18

SUMMARY OF BPT TREATMENT EFFECTIVENESS AT LEAD SUBCATEGORY PLANTS

DCP Data - Plants Meeting BPT Flow

ID	D/I*	Cr	Cu	Pb	Ni	Zn	Fe	O&G	TSS	pH
A	D		0.1	0.05			0.3		5548	
B	I			1.0					26	7.8
C	I			3.5			23.4		150	6.5
D	I			1			1.5		20	7.28
E	D			0.28					46	
F	I			1						

Industry Survey Data - Plants Meeting BPT Flow

ID	D/I*	Cr	Cu	Pb	Ni	Zn	Fe	O&G	TSS	pH
G	I			3.36					4810	7.41
H	I			0.5						8
I	I			2.3						8.2
J	I			1.1						9.0
K	D			.24					29	7.67
L	I								90	7.5
M	I			0.25						6.92

*D/I - Direct or Indirect Discharge

TABLE IX-18 (Continued)

SUMMARY OF BPT TREATMENT EFFECTIVENESS AT LEAD SUBCATEGORY PLANTS

Sampled Plants With BPT Treatment

ID	Sampling Day	Cr	Cu	Pb	Ni	Zn	Fe	O&G	TSS	pH
A	1	0.000	0.000	1.350	0.000	0.000	0.000	10.0	90.6	6.5-8.5
	2	0.010	0.040	4.050	0.000	0.710	0.000	9.9	76.0	7.2-8.8
	3	0.005	0.034	3.580	0.012	0.590	0.000	5.0	39.8	6.6-7.9
J	1	0.010	0.059	6.06	0.110	0.165	0.420	2.3	3.5	6.0-10.4
	2	0.010	0.050	3.880	0.068	0.000	0.280	1.7	11.0	7.7-9.2
	3	0.059	0.090	13.30	0.046	0.105	3.380	3.7	66.0	7.0-9.0
M	1	0.000	0.023	0.000	0.31	0.15	0.000	0.000	33.0	NA
	2	0.000	0.012	0.000	0.35	0.000	0.000	0.000	25.0	7.11
N1/	1	0.000	0.018	0.110	0.011	0.000	0.760	1.4	13.0	9.0-9.3
	2	0.005	0.014	0.130	0.009	0.000	0.920	2.7	11.0	8.7-9.1
	3	0.005	0.019	0.110	0.011	0.037	0.950	2.2	11.0	8.6-9.1
(Industry Survey Data)				0.09					30.0	7.6
O1/	1	0.000	0.05	0.1	0.000	0.000	0.1	9.0	140.0	9.0
	2	0.000	0.000	0.07	0.000	0.000	0.000	0.000	46.0	9.0
	3	0.000	0.000	0.19	0.000	0.000	0.000	2.0	25.0	9.0
(Industry Survey Data)				0.14					7	8.76
P1/		0.00	0.000	0.100	0.000	0.080	0.200	NA	NA	NA
(Industry Survey Data)				13.2					67	6.6

1/ These plants did not meet the BPT Flow.

NA - Not Available

TABLE IX-19

SAMPLE DERIVATION OF THE BPT 1-DAY LEAD LIMITATION

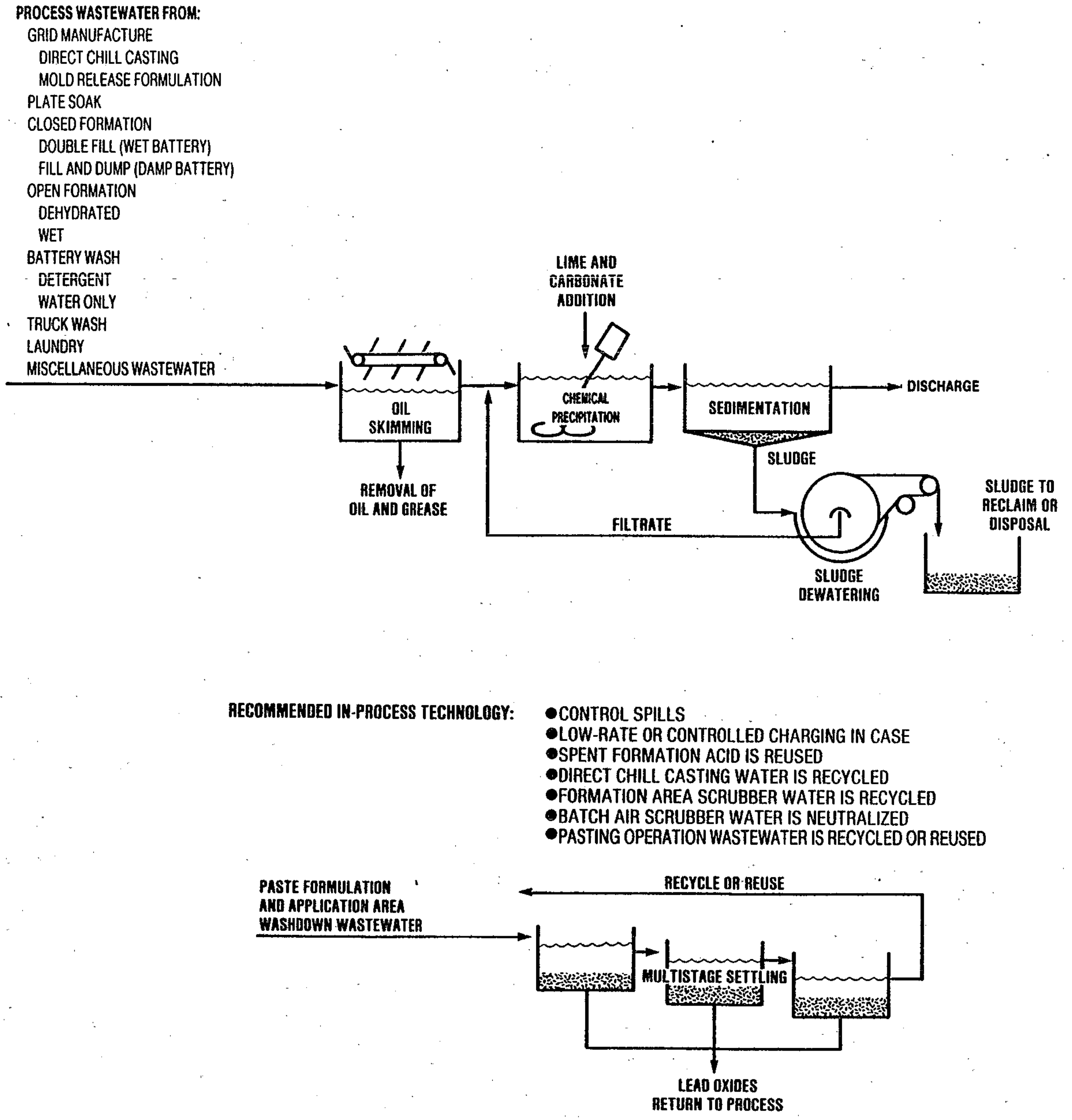
Process Elements	PNP kg/yr (10^6)	Avg. PNP (kg/day)	1-Day Limits (mg/kg)1/	Lead Mass Discharge (mg/day)2/
1. Leady Oxide Purchased	2.6	10400	0.0	0.0
2. Paste Prep. & Application	5.2	20800	0.0	0.0
3. Curing - Stacked	5.2	20800	0.0	0.0
4. Formation - Closed, Single	4.16	16640	0.0	0.0
5. Formation - Open, Dehydrated	1.04	4160	4.64	19,302
6. Battery Wash - With Detergent	5.2	20800	0.38	7,904
7. Miscellaneous (Hand Wash, Respirator Wash, and Floor Wash) 3/	5.2	20800	0.18	3,744

TOTAL Plant X Discharge (1-Day Value for Lead): 30,950 mg/day (0.68 lb/day)

1/ l/kg of lead used from Table IX-1 multiplied by lime and settle treatment concentrations (mg/l) from Table VII-21.

2/ Average PNP multiplied by the 1-day limits in Tables IX-9, IX-12, and IX-16, then each process summed for the plant's daily discharge limit.

3/ Plant indicates hand wash, respirator wash, and floor wash; therefore, plant receives total miscellaneous wastewater allowance.



RECOMMENDED IN-PROCESS TECHNOLOGY:

- CONTROL SPILLS
- LOW-RATE OR CONTROLLED CHARGING IN CASE
- SPENT FORMATION ACID IS REUSED
- DIRECT CHILL CASTING WATER IS RECYCLED
- FORMATION AREA SCRUBBER WATER IS RECYCLED
- BATCH AIR SCRUBBER WATER IS NEUTRALIZED
- PASTING OPERATION WASTEWATER IS RECYCLED OR REUSED

FIGURE IX-1. LEAD SUBCATEGORY BPT TREATMENT

SECTION X
BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The effluent limitations presented in this section apply to existing direct dischargers. A direct discharger is a site which discharges or may discharge pollutants into waters of the United States. These effluent limitations which were to be achieved by July 1, 1984, are based on the best available control and treatment technology employed by a specific point source within the industrial category or subcategory, or by another industry where it is readily transferrable. Emphasis is placed on additional treatment techniques applied at the end of the treatment systems currently employed for BPT, as well as improvements in reagent control, process control, and treatment technology optimization.

The factors considered in assessing the best available technology economically achievable (BAT) include the age of equipment and plants involved, the processes employed, process changes, non-water 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 universally 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. This level of technology also considers those plant processes and control and treatment technologies which at pilot plant and other levels have demonstrated both technological performance and economic viability at a level sufficient to justify investigation.

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. 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 were available and applicable to the battery manufacturing subcategories, and to suggest technology trains which would reduce the discharge of toxic pollutants remaining after application of BPT. The statutory assessment of BAT considers costs, but does not require a balancing of costs against effluent reduction benefits [see Weyerhaeuser v. Costle, 11 ERC 2149 (D.C. Cir. 1978)].

In a draft development document that was given limited circulation in September, 1980 to battery manufacturers and others who requested to receive a copy, a number of alternative BAT systems were described for the lead subcategory. Comments from this limited, but technically knowledgeable audience were used, together with further review and analysis of available data, in refining these alternatives and in making the selection of a specific BAT option for the lead subcategory. Some options originally presented in the draft development document were eliminated from consideration, and others were modified on the basis of comments received and other reevaluation.

At proposal, four technology options were considered as a basis for development of BAT limitations for this subcategory. These options are built incrementally upon BPT (option 0) and achieve either reduced process wastewater volume or reduced effluent pollutant concentrations in comparison with the previous option. All of the in-process controls included in these options were observed in practice within the lead subcategory. Some end-of-pipe technologies transferred from other industrial categories were considered as well as those that were practiced at lead subcategory plants.

For promulgation, four technology options were considered as a basis for development of BAT limitations. BAT options 1 to 3 remain unchanged from proposal except reuse of treated water for hose washdown is added as an in-process technology. The treatment scheme for BAT option 4 was revised, and an additional in-process technology, reuse of treated water for truck washing activities, was added. The revised option 4 treatment scheme was determined after carefully reviewing comments received on the proposed regulation.

BAT Options Summary

In summary form, the treatment technologies which were considered for the lead subcategory of the battery manufacturing category are:

Option 0 for this subcategory (Figure IX-1, page 583) consists of the following technologies:

a) In-process technology:
  - control spills
  - low-rate or controlled charging in case
  - reuse of spent formation acid in all but open wet formation
  - multiple stage settling and total recycle

or reuse of pasting operations wastewater
- direct chill casting water recycle
- recycle of formation area scrubber water
- Neutralize batch air scrubber water

b) End-of-pipe treatment:
- oil skimming
- lime precipitation augmented with carbonate
- sedimentation
- sludge dewatering

Option 1 (Figure X-1, page 616) includes all aspects of option 0 and builds on it by adding the following:

a) In-process technology:
- countercurrent rinse of electrodes after open case formation
- eliminate or recycle process water for plate dehydration
- reuse of treated water for hose washdown activity
- water rinse for batteries prior to detergent wash
- reuse of detergent rinse as makeup to detergent tank
- countercurrent rinse of batteries
- reuse of battery rinse water from battery wash with water only or closed formation case rinsing

b) End-of-pipe treatment for this option is unchanged from option 0.

Option 2 (Figure X-2, page 617) builds on option 1 with improved end-of-pipe treatment.

a) In-process technology is unchanged from option 1.

b) End-of-pipe treatment in addition to option 1:
- polishing filtration (multimedia filter)

Option 3 (Figure X-3, page 618) builds on option 2 with revision of end-of-pipe treatment.

a) In-process technology is unchanged from option 1.

b) End-of-pipe treatment consist of the following treatment steps:
- oil skimming
- chemical precipitation using sulfide
- sedimentation
- polishing filtration using membrane filters
- sludge dewatering

Option 4 (Figure X-4, page 619) provides improved end-of-pipe treatment and additional in-process technology.

a) In-process technology
   - all in-process technologies of option 1
   - recycle of permeate from reverse osmosis to the manufacturing process
   - reuse of treated water for truck washing activites

b) End-of-pipe treatment consists of the following treatment steps:
   - oil skimming
   - filtration (mixed media or membrane) of selected streams
   - reverse osmosis of selected streams
   - lime precipitation of brine and remaining streams augmented with carbonate
   - sedimentation of treated brine
   - filtration (membrane type) of treated brine
   - sludge dewatering.

Option 1

Option 1 continues the end-of-pipe treatment of option 0 (BPT) and adds improved in-process controls to reduce the amount of wastewater treated and discharged. The in-process flows for each process element for option 1 (and also options 2 and 3) are presented in Table X-1 (page 598). All in-process control techniques included in option 0 are continued as part of this treatment and control option. As described in Section IX, the following process elements have a zero discharge allowance at option 0: leady oxide production; paste preparation and application; curing; and closed formation of single-fill batteries. Under option 1, zero discharge allowances are also established for closed formation of double fill and fill and dump batteries, and water only battery wash. Decreased regulatory flows are established at option 1 for open formation dehydrated plates, detergent battery wash and miscellaneous wastewaters (specifically the floor wash flow). The in-process controls used as the basis of these option 1 flows are discussed below:

Closed Formation - All wastewater discharges from closed formation processes are eliminated by application of one or more of the in-process controls included under the option 1 technology. All of these controls are presently observed within the subcategory. Specific in-process controls included are:

- Low rate or controlled charging (from Option 0) or recycle of contact cooling water with reuse of overflow
- Control of spillage in electrolyte filling and

and dumping to reduce case contamination and eliminate battery rinsing; or recirculation of rinse water with reuse of overflow.

Slow charging or controlled charging rates used in closed formation eliminate the use of contact cooling water and the resultant process wastewater discharge. Contact cooling water used in higher rate formation processes may be recycled through a cooling tower and neutralized as required. Widespread practice of these techniques is illustrated in Table X-1; 31 of 43 reporting plants report no process wastewater discharge from closed case single fill formation processes.

Appropriate care and technology in filling batteries with acid electrolyte prior to formation, limits or eliminates 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 or refill of the electrolyte is also required. Production by single fill techniques simplifies the controls which must be employed, since only the single-filling operation (there is 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. These practices limit or eliminate the requirement for battery rinsing or washing prior to further handling or shipment, reducing or eliminating 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 recycle of the battery rinse water and reuse of the overflow in acid cutting.

Where recycle is used to reduce or eliminate wastewater discharges associated with closed formation processes, some blowdown or a bleed from the system may be needed. The overflow, or blowdown, streams discussed above may be directed to either the acid cutting or paste preparation processes. Both of these operations have negative water balances and together require about 0.4 l/kg of makeup water. These reuse practices have been observed at existing plants.

Combinations of these spill control and water reuse technologies can be employed to reduce wastewater discharge to zero from closed case formation. As shown in Table X-1, some plants are now achieving this wastewater control level; 39 of 91 plants report no process wastewater discharge from closed formation.

For double fill operations, seven of the 35 plants active in this operation reported attaining zero discharge. For fill and dump operations, one of the 13 plants active in this operation reported zero discharge. These plants demonstrate that spill control and water reuse practices can be used to reduce the option 0 wastewater discharge flow from these closed formation processes (0.45 l/kg) to zero. Therefore, a zero discharge allowance is established for option 1 for these process elements.

Open Formation - Dehydrated Batteries - Significant reductions in process wastewater discharges from the formation and dehydration of plates for dehydrated batteries are achieved by several in-process control techniques, including:

- 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

Countercurrent cascade rinsing and rinse flow control can provide significant reductions in wastewater discharge from rinsing electrodes after open formation. The achievable reduction is discussed in Section VII. Although countercurrent and multi-stage rinses after open formation are reported by a number of plants in this subcategory, these techniques are not coupled with effective rinse flow control. Consequently, they may not achieve substantially reduced wastewater discharge volumes compared to single-stage rinses. As an alternative to countercurrent rinsing and strict rinse flow control, rinse wastewater may be recycled for reuse in plate rinsing either before or after treatment. Because this technique affords lower rinsing efficiency than countercurrent cascade 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 such as steam dehydrating or the use of inert gas. These results are achieved by many plants producing dehydrated batteries, although most plants did not specifically identify the techniques employed.

Two of the 42 plants reporting open formation of dehydrated plates also reported zero discharge from this operation. As discussed above, significant reductions in process wastewater discharge from the formation and dehydration of plates for dehydrated batteries can be achieved by several in-process control techniques including; countercurrent cascade rinsing and rinse flow control; recycle of treated wastewater for plate rinses; and elimination or recycle of process water used in plate dehydration. The regulatory flow at option 1 for open formation of dehydrated batteries was calculated in the following manner. As described in Section IX, the flow used for determining BPT mass discharge limitations for this subcategory is 11.05 l/kg. This consists of water from the plate dehydration area and from the plate washing area. The application of two-stage countercurrent cascade rinsing to plate washing will achieve a water reduction factor of 6.6 (see Section VII). Treatment and reuse of water in the plate dehydration area will achieve an equivalent water use reduction. The option 1 flow of 1.68 l/kg is derived by applying the water reduction factor of 6.6 to the BPT flow of 11.05 l/kg. This flow appears to be reasonable because some plants have eliminated plate dehydration wastewater, and additional stages of countercurrent rinsing could further reduce rinse water flow.

Battery Wash - At Option 1, water only washing of batteries has been limited to a zero discharge allowance and the regulatory flow for detergent washing of batteries has been reduced. In-process control techniques for the reduction of wastewater discharges from battery washing with detergent operations include use of efficient acid addition and removal techniques as discussed previously. Also, water used for prerinsing, reducing the need for detergent water, removes electrolyte splashes from battery cases and may be recycled. Blowdown from this recycle can be used in some cases in paste formulating, or primarily in acid cutting. As discussed in Section VII, many plants visited demonstrated significant overuse of water in these battery wash operations. Simple cutback in the water used per battery by flow reduction through the nozzles is feasible. Use of mechanical switching devices to prevent water flow when batteries are not present has a significant impact on water use. The use of automatic washers typically includes a final water only rinse after the detergent wash. This final rinse water may be reused as makeup for the detergent wash cycle since it already contains detergent and it would also be more economical for the plant. Wastewater from rinses of detergent at this final product stage may not be amenable to reuse in other battery manufacturing operations and therefore requires a discharge allowance. The option 1 regulatory flow for detergent battery wash has been reduced to half of the BPT flow or 0.45 l/kg. This flow is based on the reuse of final rinse water as makeup to the detergent portion of the battery wash system. Non-detergent (initial) rinse water can be reused in detergent wash or can be rerouted to acid cutting operations.

Nondetergent rinses (battery wash with water only) seen frequently in battery manufacturing operations (44 of 66 plants) can be recycled and reused, eliminating a wastewater discharge from this type of battery wash. Techniques for reducing flow, segregating by recycle, and reuse possibilities are discussed in Section VII and above under closed formation and battery wash with detergent. Wash water removes water soluble components such as acid and lead which do not preclude reuse of the water in electrolyte. A discussed in Section VII, the buildup of key contaminants can be monitored to allow the reuse of this water without infringing on established engineering specifications for product purity. A zero discharge allowance has been established for water only battery wash at option 1 based on reuse of this water in acid cutting.

Miscellaneous Wastewater - The miscellaneous regulatory flow for option 1 is decreased from the option 0 (BPT) flow to 0.307 l/kg due to a reduction in the normalized flow for the floor wash operation. From site visits, primarily after proposal, it was found that a number of plants use wet floor scrubbing techniques and extensively use power floor scrubbers for efficient cleanup. In order to protect the power scrubbers from contamination or corrosion, these machines should use fresh water only. For hoses and bucket and mop operations, however, the use of treated wastewater is feasible and is recommended as the flow reduction technique for this process element at option 1.

The floor wash normalized flow has been reduced to 0.01 l/kg. This is based on a flow weighted average of data from plants using advanced floor washing techniques. This regulatory flow can easily be achieved by the use of commercial floor washing machines, careful spill maintenance, dry floor cleaning techniques, and recycle of treated water for reuse in hoses.

Option 2

Option 2 consists of the in-process technologies set forth in option 1 plus end-of-pipe treatment consisting of oil skimming, pH adjustment using lime augmented by carbonate precipitation, settling, and mixed media filtration. This is a conventional system which should be almost as effective in lead removal as option 3.

Option 3

Option 3 continues all of the in-process control technologies included in option 1 and adds improved end-of-pipe treatment. For this option the end-of-pipe treatment consists of oil skimming, pH adjustment with lime, chemical precipitation with sulfide, sedimentation, and polishing filtration. A membrane filter was included to achieve maximum reduction of suspended solids. 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.

Option 4

The treatment technologies included in option 4 are oil skimming, membrane filtration, reverse osmosis, lime precipitation, and sludge dewatering. As discussed earlier, option 4 has been revised for the promulgated regulation. In the revised option 4 treatment scheme, process water is segregated such that certain less concentrated streams are directed through filtration and subsequently reverse osmosis. The reverse osmosis brine and the remaining process water streams are commingled for treatment by lime precipitation and the treated water is filtered and discharged. Both sets of streams are initially treated by oil skimming and the permeate from reverse osmosis (50 percent of reverse osmosis influent) is recycled after treatment back to the manufacturing process.

In addition, treated water is reused for truck washing activities.

BAT OPTION SELECTION

The BAT options were carefully evaluated, and the technical merits and disadvantages of each were compared. Quantitative estimates were prepared using all available data for each plant in the subcategory. As a part of this evalution, a theoretical "normal" plant was developed. This normal plant is defined as a theoretical plant which has each of the manufacturing process elements covered by the subcategory at a production level that is the average level of all plants in the subcategory. While no such entity is known to exist, it is a useful concept in evaluating the pollutant reduction benefits of various options, and appraising the importance of toxic and other pollutant discharges.

The EPA data base was used as a basis for generating the normal plant profile and data. All 186 plants in the data base supplied some data. Where data was lacking, the nonresponding plants were presumed to be similiar to the average of those that supplied information. Normal plant production normalizing parameter equivalents (million kg/yr of lead) and flow (million l/yr) are displayed for each lead subcategory process in Table X-2 (page 599).

An evaluation of the lead subcategory indicates that plants which discharge process wastewater tend to have higher productions than those which achieve zero discharge. As discussed earlier, data from all plants (both dischargers and zero dischargers) were used to develop the normal plant. Therefore, productions and flows at a typical discharging plant will be higher than those at the normal plant. In order to determine pollutant reduction benefits for plants which discharge wastewater, the normal plant was used to develop a normal discharging plant. This plant is a theoretical plant which has each of the manufacturing process elements at a production level that is the average level of direct and indirect dischargers in the subcategory. The productions and flows of the normal discharging plant are approximately 1.3 times the normal plant values shown in Table X-2. The normal discharging plant was used to estimate pollutant removal benefits for all discharging plants, direct dischargers, and indirect dischargers.

In Section V the average pollutant concentrations in lead subcategory process elements were described and displayed in Table V-5 (page 178). These raw waste concentrations are used as the basis for calculating treatment effectiveness and pollutant removal benefits of the several technology options. Treatment effectiveness is based on both in-process controls and end-of-pipe treatment. Treatment effectiveness calculations are summarized in Table X-3 (page 601), benefits are displayed in Tables X-4 (for the normal plant) (page 602), X-5 (for the normal discharging plant) (page 603), X-6 (for all discharging plants) (page 604), and X-7 (for direct discharging plants) (page 605). The first step involved in calculating pollutant reduction benefits for the normal plant was to estimate raw waste generation. To calculate normal plant raw waste generation, the raw normal plant flow (l/yr (10^6)) shown in Table X-2 for each process element was multiplied by the corresponding process element pollutant concentrations (mg/l) shown in Table V-5 (page 178). The raw waste generation (kg/yr) for the individual process elements were then summed to determine the total raw waste generated by the normal plant. Pollutant reduction benefits of each treatment and control alternative were calculated using the raw waste generation, the normal plant effluent discharge flow for the option (see Table X-2), and the treatment effectiveness concentrations. The normal plant effluent discharge flow (l/yr (10^6)) was multiplied by the treatment effectiveness concentrations (mg/l) (Table VII-21, page

418) to determine the total mass of pollutants discharged annually (kg/yr) with the control and treatment alternative. The mass of pollutants removed by the control and treatment alternative is the difference between raw waste and pollutants discharged.

Pollutant reduction benefits for the normal discharging plant were determined in a similar manner to those for the normal plant. Total discharging plant benefits were calculated by multiplying the normal discharging plant benefits by 111 (there are 111 plants which currently discharge wastewater in the lead subcategory). The 19 plants in the subcategory which have closed were not included in the total discharging plant benefits. Benefits for direct dischargers were determined by multiplying the normal discharging plant benefits by eight (there are eight active direct dischargers in the subcategory).

The Agency proposed Option 1 as the basis for BAT but also stated that consideration would be given to establishing Option 2 as BAT at promulgation. Both of these options were carefully evaluated since proposal. As part of this evaluation after proposal, required capital and total annual compliance costs for technology options 1 and 2 for the lead subcategory were estimated. These estimates were developed by estimating costs for each active discharging plant (85 plants) in the subcategory based on reported production and wastewater flows, and summing the costs for each level of treatment and control. Compliance costs were not estimated for closed plants; there are no compliance costs for the 57 zero dischargers in the subcategory. Twenty-six plants in the lead subcategory did not report sufficient production or flow data to be costed. In order to include these plants in the subcategory total of 186, the characteristics available in the data base were used, primarily number of employees, to establish general plant size. The average plant cost for those analogous plants which had been costed was assigned to each of those plants with insufficient data to establish a cost for this group of plants. The results of these lead subcategory cost calculations are shown in Table X-8. An economic impact analysis based on estimated costs indicates that there are no potential plant closures projected for these options.

EPA has selected option 1, presented in Figure X-1 (page 616), as the basis for BAT effluent limitations because it removes over 99.9 percent of the toxic metals and other pollutants from estimated raw waste and is economically achievable. The Agency has decided not to include filtration as part of the model BAT treatment technology (Option 2). EPA has concluded that compliance with promulgated limitations based on option 1 will remove practically all the toxic and other pollutants from lead battery manufacturing wastewater discharges. Further treatment would result only in insignificant reductions in annual national discharges.

REGULATED POLLUTANT PARAMETERS

The pollutant parameters listed in Tables VI-1 and VI-2 (pages 296 and 301) as being considered for regulation were used to select the specific pollutants to be regulated in the lead subcategory. The selection of toxic pollutants for regulation was based primarily upon the presence of the pollutant at treatable concentrations in lead subcategory raw waste streams. Plants in the lead subcategory have a variety of different combinations of process elements, but, in general, the same pollutants are detected in significant concentrations for all processes. Other pollutants, not specifically regulated, would also be controlled by the removal of the selected pollutants. The overall costs for monitoring and analysis would therefore be reduced. Nonconventional pollutants are regulated as appropriate when found at treatable concentrations. Conventional pollutants (pH, TSS and O&G) are not regulated under BAT, except where one might be used as an indicator, but are generally considered under BCT.

Pollutant parameters regulated at BAT for this subcategory are lead, copper and iron. Antimony, cadmium, chromium, mercury, nickel, silver, zinc, aluminum, and manganese which appeared at lower concentrations and were considered, but not selected for regulation at BAT, are expected to be adequately removed by the application of the selected technology.

The conventional pollutant parameters, oil and grease, total suspended solids and pH are not regulated under BAT, but are considered under BCT.

POLLUTANT REMOVALS AND COSTS

In establishing BAT, EPA considered the cost of treatment and control and the pollutant reduction benefits to evaluate economic achievability. The application of BAT to the lead subcategory will remove 115,604 kilograms (254,330 pounds) per year of toxic metals and 679,114 kilograms (1,494,050 pounds) per year of other pollutants from the estimated raw waste of direct dischargers. The associated capital cost, above equipment in place is $0.819 million ($1983) and the total annual cost is $0.510 million ($1983). These costs assume that plants will install BAT treatment at the BAT regulatory flow. The Agency has determined that the BAT limitations are economically achievable.

EFFLUENT LIMITATIONS

The effluent concentrations attainable through the application of BAT technology are displayed in Table VII-21 under L&S technology. The BAT mass discharge limitations can be calculated by multiplying these concentrations by the applicable BAT regulatory flows listed in Table X-1. These limitations are expressed in terms of mg of pollutant per kg of lead used in the product and are presented in Tables X-9 to X-17 (pages 607 to 615). By multiplying these limitations by the actual production within a process element, the allowable mass discharge for that process element can be calculated. The allowable pollutant discharge for the different process elements can be summed to determine the total allowable mass discharge for the plant. In the limitation tables, all the pollutants which were considered for regulation are listed and those selected for regulation are *'d.

The reasonableness of these BAT limitations is based upon two premises - the demonstrated ability to achieve the flow levels and the proven ability of the lime and settle technology to achieve the designated effluent concentrations. The flows used as a basis to calculate BAT mass discharge limitations are based upon demonstrated performance at lead subcategory plants. By process substitution or in-process controls, lead battery manufacturing plants can meet the option 1 based flow levels. Every process element within the lead subcategory for which a zero regulatory flow has been established is known to be performed without wastewater discharge in at least one plant. Table X-1 includes a summary of the number of plants which are active in each process element but do not discharge wastewater as a result of these process elements.

TABLE X-1

PROCESS ELEMENT FLOW SUMMARY
LEAD SUBCATEGORY

PROCESS ELEMENT	No. Plants Reporting Flow Data	No. Plants Reporting Zero Discharge	Median Flow l/kg	Mean Flow l/kg	BPT (PSES 0) Flow l/kg	BAT (PSES) 1,2,&3 l/kg	BAT (PSES 4) Flow l/kg
ANODES AND CATHODES							
Leady Oxide Production	41	29	0.00	0.37	0.00	0.00	0.00
Grid Manufacture							
Mold Release Formulation	2 (29)	0	*	0.006	0.006	0.006	0.003†
Direct Chill Casting	1	0	0.0002	0.0002	0.0002	0.0002	0.0001†
Lead Rolling	1	5 2/	0.006	0.006	0.006	0.006	0.006
Paste Preparation and Application	100	57	0.00	0.49	0.00	0.00	0.00
Curing	97	87	0.00	0.03	0.00	0.00	0.00
Closed Formation (In Case)							
Single Fill	43	31	0.00	0.28	0.00	0.00	0.00
Double Fill	35	7	0.45	0.92	0.45	0.00	0.00
Fill and Dump	13	1	0.45	1.83	0.45	0.00	0.00
Open Formation (Out of Case)							
Dehydrated	42	2	11.05	28.26	11.05	1.68	0.84†
Wet	16	10	0.00	0.36	0.053	0.053	0.053
Plate Soak	3	0	0.021	0.026	0.021	0.021	0.021
ANCILLARY OPERATIONS							
Battery Wash							
Detergent	22	0	0.90	1.70	0.90	0.45	0.23†
Water Only	44	1	0.59	3.47	0.59	0.00	0.00
Floor Wash	+ 13	2	0.13	0.11	0.13	0.01	0.01
Wet Air Pollution Control	+ 56 1/	32 1/	0.00	0.26	0.011	0.011	0.011
Battery Repair	+ 3	0	0.25	0.20	0.25	0.25	0.25
Laboratory	+ 4	0	*	0.003	0.003	0.003	0.003
Truck Wash	2	0	0.014	0.014	0.014	0.014	0.005
PERSONAL HYGIENE							
Hand Wash	+ 2 (63)	0	*	0.027	0.027	0.027	0.027
Respirator Wash	+ 6 (51)	0	*	0.006	0.006	0.006	0.006
Laundry	2 (11)	0	*	0.109	0.109	0.109	0.109
MISCELLANEOUS (Elements marked "+" are included)					0.427	0.307	0.307

1/ Based on number of scrubbers from all process areas but laboratories.
2/ Lead rolling spent emulsion is contract hauled by five plants; flow data is available from one of these plants.
( ) Number of plants used to calculate l/kg flow per unit operation
† Flow reduction at this option based on 50% water reuse using reverse osmosis.
* Calculated as flow weighted average - no median available

TABLE X-2

NORMAL PLANT ELEMENT FLOWS
LEAD SUBCATEGORY

Process Element	PNP Equivalent kg/yr lead (10^6)	Normal Plant Flow, l/yr (10^6) RAW	BPT (PSES 0)	BAT 1,2,3 (PSES 1,2,3)	BAT 4 (PSES 4)
Leady Oxide	5.440				
Produced On Site	2.928	1.083	0	0	0
Purchased	2.512				
Grid Manufacture					
Direct Chill Casting	0.648	0.0001	0.0001	0.0001	0.00005
Mold Release Formulation	4.792	0.034	0.029	0.029	0.014
Paste Preparation & Application	5.440	2.666	0	0	0
Curing	5.440				
Stacked	4.074	0	0	0	0
Controlled Room	0.718	0	0	0	0
Steam Cure	0.648	1.24	0	0	0
Formation	5.440				
Closed Formation	4.301				
Single Fill	1.684	0.472	0	0	0
Double Fill	2.078	1.912	0.935	0	0
Fill and Dump	0.539	0.986	0.243	0	0
Open Formation	1.139				
Dehydrated	0.973	27.497	10.752	1.635	0.817
Wet	0.166	0.060	0.009	0.009	0.009
Plate Soak	0.071	0.002	0.002	0.002	0.002
Battery Wash					
With Detergent	0.289	0.491	0.26	0.13	0.066
Water Only	4.678	16.233	2.70	0	0
Wet Air Pollution Control	5.440	0.059	0.059	0.059	0.059
Floor Wash	5.440	0.707	0.707	0.05	0.05
Battery Repair	0.127	0.032	0.032	0.032	0.032
Laboratory	5.440	0.016	0.01	0.01	0.01
Truck Wash	1.422	0.020	0.020	0.020 (0.007)*	0.007

TABLE X-2 (continued)

NORMAL PLANT ELEMENT FLOWS
LEAD SUBCATEGORY

Process Element	PNP Equivalent kg/yr lead (10^6)	Normal Plant Flow, l/yr (10^6) RAW	BPT (PSES 0)	BAT 1,2,3 (PSES 1,2,3)	BAT 4 (PSES 4)
Personal Hygiene					
Hand Wash	5.440	0.147	0.14	0.14	0.14
Respirator Wash	5.440	0.033	0.03	0.03	0.03
Laundry	0.837	0.091	0.09	0.09	0.09
Total Normal Plant	5.440	53.7361	16.018	2.236 (2.223)*	1.327

*Flows used for selected new source option.

TABLE X-3

SUMMARY OF TREATMENT EFFECTIVENESS
LEAD SUBCATEGORY

PARAMETER	RAW WASTE		BPT (PSES 0)		BAT 1 (PSES 1)		BAT 2 (PSES 2)		BAT 3 (PSES 3)		BAT 4 (PSES 4)	
	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Flow (l/kg)*	9.886		2.94		0.40		0.40		0.40		0.24	
114. Antimony	0.146	1.44	0.28	0.82	0.70	0.28	0.47	0.19	0.47	0.19	0.47	0.11
118. Cadmium	0.005	0.04	0.009	0.02	0.05	0.02	0.04	0.02	0.01	0.004	0.04	0.01
119. Chromium	0.076	0.75	0.08	0.24	0.08	0.03	0.07	0.02	0.08	0.03	0.07	0.01
120. Copper	0.175	1.73	0.50	1.47	0.58	0.23	0.39	0.15	0.05	0.02	0.39	0.09
122. Lead	205.822	2034.84	0.12	0.35	0.12	0.04	0.08	0.03	0.01	0.004	0.08	0.01
123. Mercury 1/	80.0	800.0	200.0	760.0	0.584	0.234	0.584	0.234	0.584	0.234	0.986	0.237
124. Nickel	0.073	0.72	0.23	0.69	0.74	0.30	0.22	0.09	0.05	0.02	0.22	0.05
126. Silver 1/	190.0	1800.0	3.00	8.82	2.24	0.919	2.24	0.919	2.24	0.919	3.79	0.918
128. Zinc	0.487	4.81	0.33	0.97	0.33	0.13	0.23	0.09	0.01	0.004	0.23	0.05
Aluminum	0.287	2.83	0.68	2.00	2.24	0.91	1.49	0.60	1.49	0.60	1.49	0.36
Iron	4.566	45.14	0.41	1.20	0.41	0.16	0.28	0.11	0.28	0.11	0.28	0.06
Manganese	0.038	0.37	0.12	0.36	0.16	0.06	0.14	0.05	0.14	0.05	0.14	0.03
Oil&Grease	54.605	539.84	10.00	29.42	10.00	4.09	10.00	4.09	10.00	4.09	10.00	2.42
TSS	1154.747	11416.32	12.00	35.31	12.00	4.91	2.60	1.06	2.60	1.06	2.60	0.62

*Normalized flow based on total subcategory lead weight.

1/ Mercury and silver units are mg/l x 10^{-4} and mg/kg x 10^{-4}.

TABLE X-4

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LEAD SUBCATEGORY - NORMAL PLANT

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3		BAT 4 & PSES 4	
	kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr
FLOW l/yr (10^6)	53.78		16.009		2.227		2.227		2.227		1.318
114 Antimony	7.85	3.38	4.474	6.29	1.558	6.80	1.046	6.80	1.046	7.23	0.619
118 Cadmium	0.29	0.16	0.127	0.20	0.094	0.20	0.094	0.27	0.022	0.23	0.064
119 Chromium	4.08	2.74	1.344	3.89	0.187	3.93	0.155	3.90	0.178	3.99	0.092
120 Copper	9.46	1.45	8.006	7.51	1.955	8.59	0.868	9.35	0.111	8.95	0.514
122 Lead	11068.96	11067.04	1.921	11068.69	0.267	11068.78	0.178	11068.94	0.022	11068.86	0.105
123 Mercury	0.44	0.03	0.411	0.44	0.000	0.44	0.000	0.44	0.000	0.44	0.000
124 Nickel	3.92	0.14	3.782	2.27	1.647	3.43	0.489	3.81	0.111	3.63	0.289
126 Silver	1.02	1.02	0.000	1.02	0.000	1.02	0.000	1.02	0.000	1.02	0.000
128 Zinc	26.19	20.91	5.282	25.46	0.734	25.68	0.512	26.17	0.022	25.89	0.303
Aluminum	16.02	5.12	10.904	11.03	4.988	12.70	3.318	12.70	3.318	14.06	1.963
Iron	261.97	255.41	6.563	261.06	0.913	261.35	0.623	261.35	0.623	261.60	0.369
Manganese	2.15	0.18	1.973	2.15	0.000	1.84	0.311	1.84	0.311	1.97	0.184
Oil & Grease	2936.66	2776.57	160.090	2914.39	22.270	2914.39	22.270	2914.39	22.270	2923.48	13.180
TSS	62137.96	61945.85	192.108	62111.24	26.724	62132.17	5.790	62132.17	5.790	62134.53	3.426
Total Toxics	11122.21	11096.86	25.347	11115.77	6.442	11118.87	3.342	11120.70	1.512	11120.22	1.986
Total Nonconv.	280.14	260.70	19.440	274.24	5.901	275.89	4.252	275.89	4.252	277.62	2.516
Total Conv.	65074.62	64722.42	352.198	65025.63	48.994	65046.56	28.060	65046.56	28.060	65058.01	16.606
Total Pollu.	76476.97	76079.99	396.985	76415.63	61.337	76441.32	35.654	76443.15	33.824	76455.86	21.108
Sludge kg/yr		463185		465199		465418		465445		465538	

TABLE X-5

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LEAD SUBCATEGORY - NORMAL DISCHARGING PLANT

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3		BAT 4 & PSES 4	
	kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr
FLOW l/yr (10^6)	69.91		20.81		2.89		2.89		2.89		1.72
114 Antimony	10.20	4.39	5.81	8.18	2.02	8.84	1.36	8.84	1.36	9.40	0.80
118 Cadmium	0.37	0.21	0.16	0.25	0.12	0.25	0.12	0.34	0.03	0.29	0.08
119 Chromium	5.30	3.56	1.74	5.06	0.24	5.10	0.20	5.07	0.23	5.19	0.11
120 Copper	12.29	1.89	10.40	9.75	2.54	11.17	1.12	12.15	0.14	11.63	0.66
122 Lead	14389.65	14387.16	2.49	14389.31	0.34	14389.42	0.23	14389.62	0.03	14389.52	0.13
123 Mercury	0.57	0.04	0.53	0.57	0.00	0.57	0.00	0.57	0.00	0.57	0.00
124 Nickel	5.09	0.18	4.91	2.95	2.14	4.46	0.63	4.95	0.14	4.72	0.37
126 Silver	1.32	1.32	0.00	1.32	0.00	1.32	0.00	1.32	0.00	1.32	0.00
128 Zinc	34.04	27.18	6.86	33.09	0.95	33.38	0.66	34.01	0.03	33.65	0.39
Aluminum	20.82	6.65	14.17	14.34	6.48	16.51	4.31	16.51	4.31	18.27	2.55
Iron	340.56	332.03	8.53	339.38	1.18	339.75	0.81	339.75	0.81	340.09	0.47
Manganese	2.79	0.23	2.56	2.19	0.60	2.39	0.40	2.39	0.40	2.56	0.23
Oil & Grease	3817.66	3609.55	208.11	3788.71	28.95	3788.71	28.95	3788.71	28.95	3800.53	17.13
TSS	80779.35	80529.61	249.74	80744.61	34.74	80771.83	7.52	80771.83	7.52	80774.90	4.45
Total Toxics	14458.83	14425.93	32.90	14450.48	8.35	14454.51	4.32	14456.87	1.96	14456.29	2.54
Total Nonconv.	364.17	338.91	25.26	355.91	8.26	358.65	5.52	358.65	5.52	360.92	3.25
Total Conv.	84597.01	84139.16	457.85	84533.32	63.69	84560.54	36.47	84560.54	36.47	84575.43	21.58
Total Pollu.	99420.01	98904.00	516.01	99339.71	80.30	99373.70	46.31	99376.06	43.95	99392.64	27.37
Sludge kg/yr		602141		604759		605044		605078		605200	

TABLE X-6

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LEAD SUBCATEGORY - TOTAL DISCHARGERS

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3		BAT 4 & PSES 4	
	kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr
FLOW l/yr (10^6)	7760.01		2309.91		320.79		320.79		320.79		190.92
114 Antimony	1132.20	487.29	644.91	907.98	224.22	981.24	150.96	981.24	150.96	1043.40	88.80
118 Cadmium	41.07	23.31	17.76	27.75	13.32	27.75	13.32	37.74	3.33	32.19	8.88
119 Chromium	588.30	395.16	193.14	561.66	26.64	566.10	22.20	562.77	25.53	576.09	12.21
120 Copper	1364.19	209.79	1154.40	1082.25	281.94	1239.87	124.32	1348.65	15.54	1290.93	73.26
122 Lead	1597251.15	1596974.76	276.39	1597213.41	37.74	1597225.62	25.53	1597247.82	3.33	1597236.72	14.43
123 Mercury	63.27	4.44	58.83	63.27	0.00	63.27	0.00	63.27	0.00	63.27	0.00
124 Nickel	564.99	19.98	545.01	327.45	237.54	495.06	69.93	549.45	15.54	523.92	41.07
126 Silver	146.52	146.52	0.00	146.52	0.00	146.52	0.00	146.52	0.00	146.52	0.00
128 Zinc	3778.44	3016.98	761.46	3672.99	105.45	3705.18	73.26	3775.11	3.33	3735.15	43.29
Aluminum	2311.02	738.15	1572.87	1591.74	719.28	1832.61	478.41	1832.61	478.41	2027.97	283.05
Iron	37802.16	36855.33	946.83	37671.18	130.98	37712.25	89.91	37712.25	89.91	37749.99	52.17
Manganese	309.69	25.53	284.16	243.09	66.60	265.29	44.40	265.29	44.40	284.16	25.53
Oil & Grease	423760.26	400660.05	23100.21	420546.81	3213.45	420546.81	3213.45	420546.81	3213.45	421858.83	1901.43
TSS	8966507.85	8938786.71	27721.14	8962651.71	3856.14	8965673.13	834.72	8965673.13	834.72	8966013.90	493.95
Total Toxics	1604930.13	1601278.23	3651.90	1604003.28	926.85	1604450.61	479.52	1604712.57	217.56	1604648.19	281.94
Total Nonconv.	40422.87	37619.01	2803.86	39506.01	916.86	39810.15	612.72	39810.15	612.72	40062.12	360.75
Total Conv.	9390268.11	9339446.76	50821.35	9383198.52	7069.59	9386219.94	4048.17	9386219.94	4048.17	9387872.73	2395.38
Total Pollu.	11035621.11	10978344.00	57277.11	11026707.81	8913.30	11030480.70	5140.41	11030742.66	4878.45	11032583.04	3038.07
Sludge kg/yr		66837651		67128249		67159884		67163658		67177200	

TABLE X-7

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LEAD SUBCATEGORY - DIRECT DISCHARGERS

PARAMETER	RAW WASTE	BPT		BAT 1		BAT 2		BAT 3		BAT 4	
	kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr
FLOW l/yr (10^6)	559.28		166.48		23.12		23.12		23.12		13.76
114 Antimony	81.60	35.12	46.48	65.44	16.16	70.72	10.88	70.72	10.88	75.20	6.40
118 Cadmium	2.96	1.68	1.28	2.00	0.96	2.00	0.96	2.72	0.24	2.32	0.64
119 Chromium	42.40	28.48	13.92	40.48	1.92	40.80	1.60	40.56	1.84	41.52	0.88
120 Copper	98.32	15.12	83.20	78.00	20.32	89.36	8.96	97.20	1.12	93.04	5.28
122 Lead	115117.20	115097.28	19.92	115114.48	2.72	115115.36	1.84	115116.96	0.24	115116.16	1.04
123 Mercury	4.56	0.32	4.24	4.56	0.00	4.56	0.00	4.56	0.00	4.56	0.00
124 Nickel	40.72	1.44	39.28	23.60	17.12	35.68	5.04	39.60	1.12	37.76	2.96
126 Silver	10.56	10.56	0.00	10.56	0.00	10.56	0.00	10.56	0.00	10.56	0.00
128 Zinc	272.32	217.44	54.88	264.72	7.60	267.04	5.28	272.08	0.24	269.20	3.12
Aluminum	166.56	53.20	113.36	114.72	51.84	132.08	34.48	132.08	34.48	146.16	20.40
Iron	2724.48	2656.24	68.24	2715.04	9.44	2718.00	6.48	2718.00	6.48	2720.72	3.76
Manganese	22.32	1.84	20.48	17.52	4.80	19.12	3.20	19.12	3.20	20.48	1.84
Oil & Grease	30541.28	28876.40	1664.88	30309.68	231.60	30309.68	231.60	30309.68	231.60	30404.24	137.04
TSS	646234.80	644236.88	1997.92	645956.88	277.92	646174.64	60.16	646174.64	60.16	646199.20	35.60
Total Toxics	115670.64	115407.44	263.20	115603.84	66.80	115636.08	34.56	115654.96	15.68	115650.32	20.32
Total Nonconv.	2913.36	2711.28	202.08	2847.28	66.08	2869.20	44.16	2869.20	44.16	2887.36	26.00
Total Conv.	676776.08	673113.28	3662.80	676266.56	509.52	676484.32	291.76	676484.32	291.76	676603.44	172.64
Total Pollu.	795360.08	791232.00	4128.08	794717.68	642.40	794989.60	370.48	795008.48	351.60	795141.12	218.96
Sludge kg/yr		4817128		4838072		4840352		4840624		4841600	

TABLE X-8

BATTERY MANUFACTURING COMPLIANCE COSTS
LEAD SUBCATEGORY

Discharge Status	Option BPT (PSES-0)		Option BAT-1 (PSES-1)		Option BAT-2 (PSES-2)	
	Capital	Annual	Capital	Annual	Capital	Annual
Direct	714,843	499,039	818,501	509,777	968,117	580,628
Indirect	7,887,805	4,635,339	7,121,534	4,072,814	8,390,881	4,723,621
Total	8,602,648	5,134,378	7,940,035	4,582,591	9,358,998	5,304,249

Discharge Status	Option BAT-3 (PSES-3)*		Option BAT-4 (PSES-4)*	
	Capital	Annual	Capital	Annual
Direct	989,487	739,521	1,619,406	930,465
Indirect	11,214,186	8,381,238	18,353,268	10,545,270
Total	12,203,673	9,120,759	19,972,674	11,475,735

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*Plant-by-plant costs were not calculated for Options 3 and 4. Option 3 and 4 costs are based on the normal discharging plant.

All costs are in June, 1983 dollars.

TABLE X-9

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Mold Release Formulation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.01	0.008
Cadmium	0.002	0.0009
Chromium	0.003	0.001
*Copper	0.011	0.006
*Lead	0.002	0.001
Mercury	0.002	0.0006
Nickel	0.01	0.008
Silver	0.0025	0.0010
Zinc	0.009	0.004
Aluminum	0.04	0.02
*Iron	0.007	0.003
Manganese	0.004	0.002

*Regulated Pollutant

TABLE X-10

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Direct Chill Lead Casting

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.00057	0.00026
Cadmium	0.00007	0.00003
Chromium	0.00009	0.00004
*Copper	0.0004	0.0002
*Lead	0.00008	0.00004
Mercury	0.00005	0.00002
Nickel	0.00038	0.00025
Silver	0.00008	0.00003
Zinc	0.00029	0.00012
Aluminum	0.0013	0.0006
*Iron	0.0002	0.0001
Manganese	0.0001	0.00006

*Regulated Pollutant

TABLE X-11

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Open Formation - Dehydrated

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	4.82	2.15
Cadmium	0.57	0.25
Chromium	0.73	0.30
*Copper	3.19	1.68
*Lead	0.71	0.34
Mercury	0.42	0.16
Nickel	3.22	2.13
Silver	0.68	0.28
Zinc	2.45	1.02
Aluminum	10.80	5.38
*Iron	2.02	1.02
Manganese	1.14	0.49

*Regulated Pollutant

TABLE X-12

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Open Formation - Wet

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.152	0.067
Cadmium	0.018	0.007
Chromium	0.023	0.009
*Copper	0.100	0.053
*Lead	0.022	0.010
Mercury	0.013	0.005
Nickel	0.101	0.067
Silver	0.021	0.009
Zinc	0.077	0.032
Aluminum	0.34	0.17
*Iron	0.06	0.03
Manganese	0.04	0.02

*Regulated Pollutant

TABLE X-13

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Plate Soak

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.060	0.026
Cadmium	0.007	0.003
Chromium	0.009	0.003
*Copper	0.039	0.021
*Lead	0.008	0.004
Mercury	0.005	0.002
Nickel	0.040	0.026
Silver	0.008	0.003
Zinc	0.030	0.012
Aluminum	0.135	0.067
*Iron	0.030	0.010
Manganese	0.014	0.006

*Regulated Pollutant

TABLE X-14

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Battery Wash (Detergent)

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	1.29	0.58
Cadmium	0.15	0.07
Chromium	0.20	0.08
*Copper	0.86	0.45
*Lead	0.19	0.09
Mercury	0.11	0.05
Nickel	0.86	0.57
Silver	0.18	0.08
Zinc	0.66	0.27
Aluminum	2.89	1.44
*Iron	0.54	0.27
Manganese	0.31	0.13

*Regulated Pollutant

TABLE X-15

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Truck Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Antimony	0.040	0.017
Cadmium	0.004	0.002
Chromium	0.006	0.002
*Copper	0.026	0.014
*Lead	0.005	0.002
Mercury	0.003	0.001
Nickel	0.026	0.017
Silver	0.005	0.002
Zinc	0.020	0.008
Aluminum	0.09	0.04
*Iron	0.016	0.008
Manganese	0.01	0.004

*Regulated Pollutant

TABLE X-16

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Laundry

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.31	0.14
Cadmium	0.037	0.016
Chromium	0.05	0.02
*Copper	0.21	0.11
*Lead	0.05	0.02
Mercury	0.027	0.011
Nickel	0.209	0.138
Silver	0.045	0.019
Zinc	0.16	0.07
Aluminum	0.70	0.35
*Iron	0.13	0.07
Manganese	0.07	0.03

*Regulated Pollutant

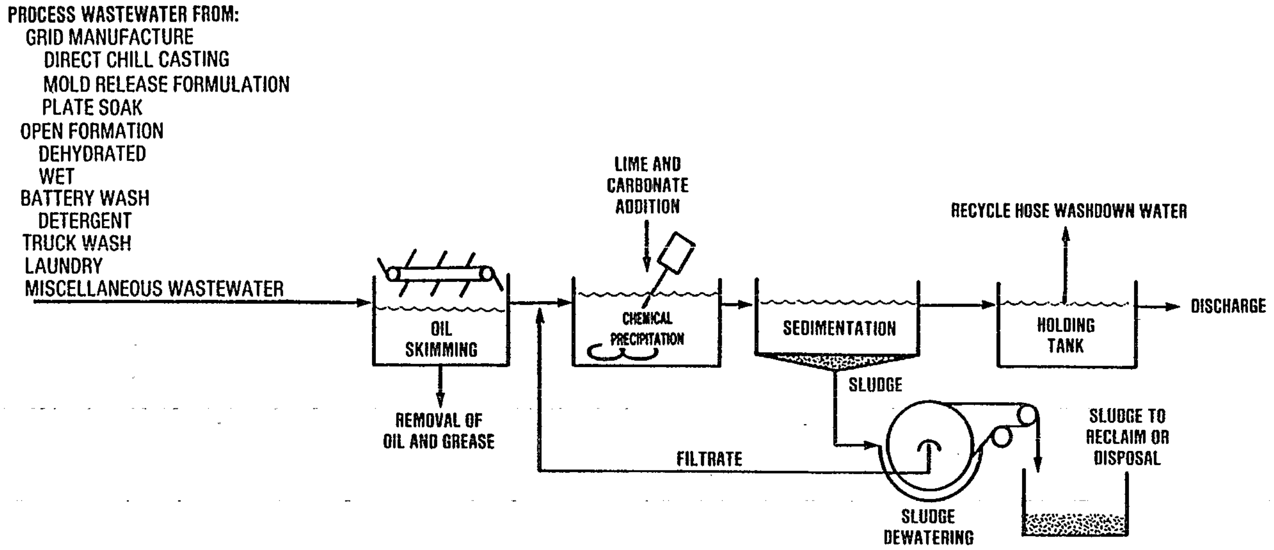
TABLE X-17

LEAD SUBCATEGORY
BAT EFFLUENT LIMITATIONS

Miscellaneous Wastewater Streams

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.88	0.39
Cadmium	0.10	0.05
Chromium	0.14	0.06
*Copper	0.58	0.31
*Lead	0.13	0.06
Mercury	0.08	0.03
Nickel	0.59	0.39
Silver	0.13	0.05
Zinc	0.45	0.19
Aluminum	1.97	0.98
*Iron	0.37	0.19
Manganese	0.21	0.09

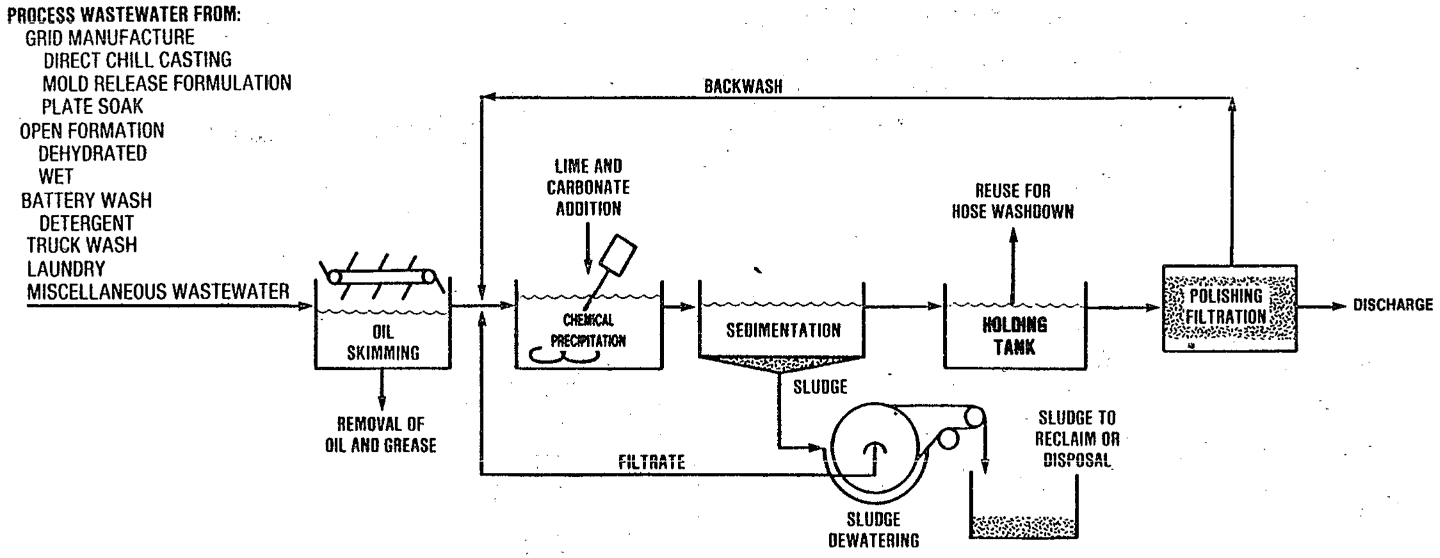
*Regulated Pollutant



ADDITIONAL RECOMMENDED IN-PROCESS TECHNOLOGY:

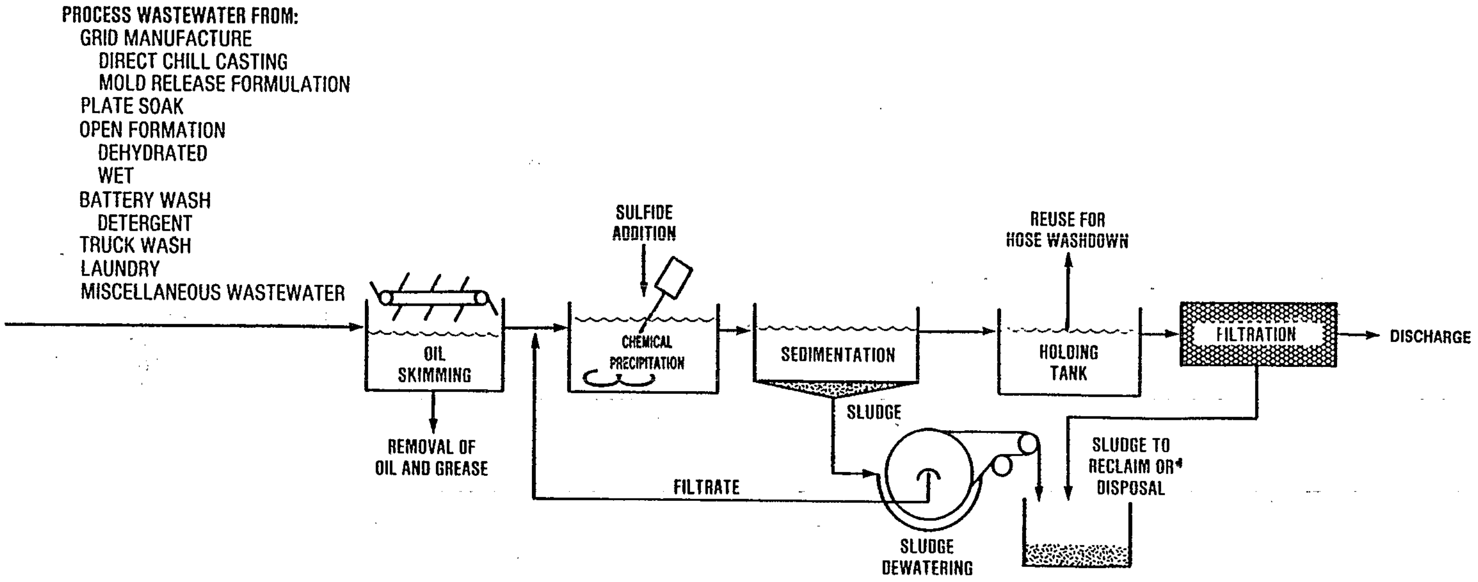
- COUNTERCURRENT RINSE ELECTRODES AFTER OPEN FORMATION
- ELIMINATE OR RECYCLE PROCESS WATER FOR PLATE DEHYDRATION
- WATER RINSE OF BATTERIES PRIOR TO DETERGENT WASH
- COUNTERCURRENT RINSE BATTERIES
- REUSE BATTERY RINSE WATER
- REUSE TREATED WATER FOR HOSE WASHDOWN

FIGURE X-1. LEAD SUBCATEGORY BAT OPTION 1 TREATMENT



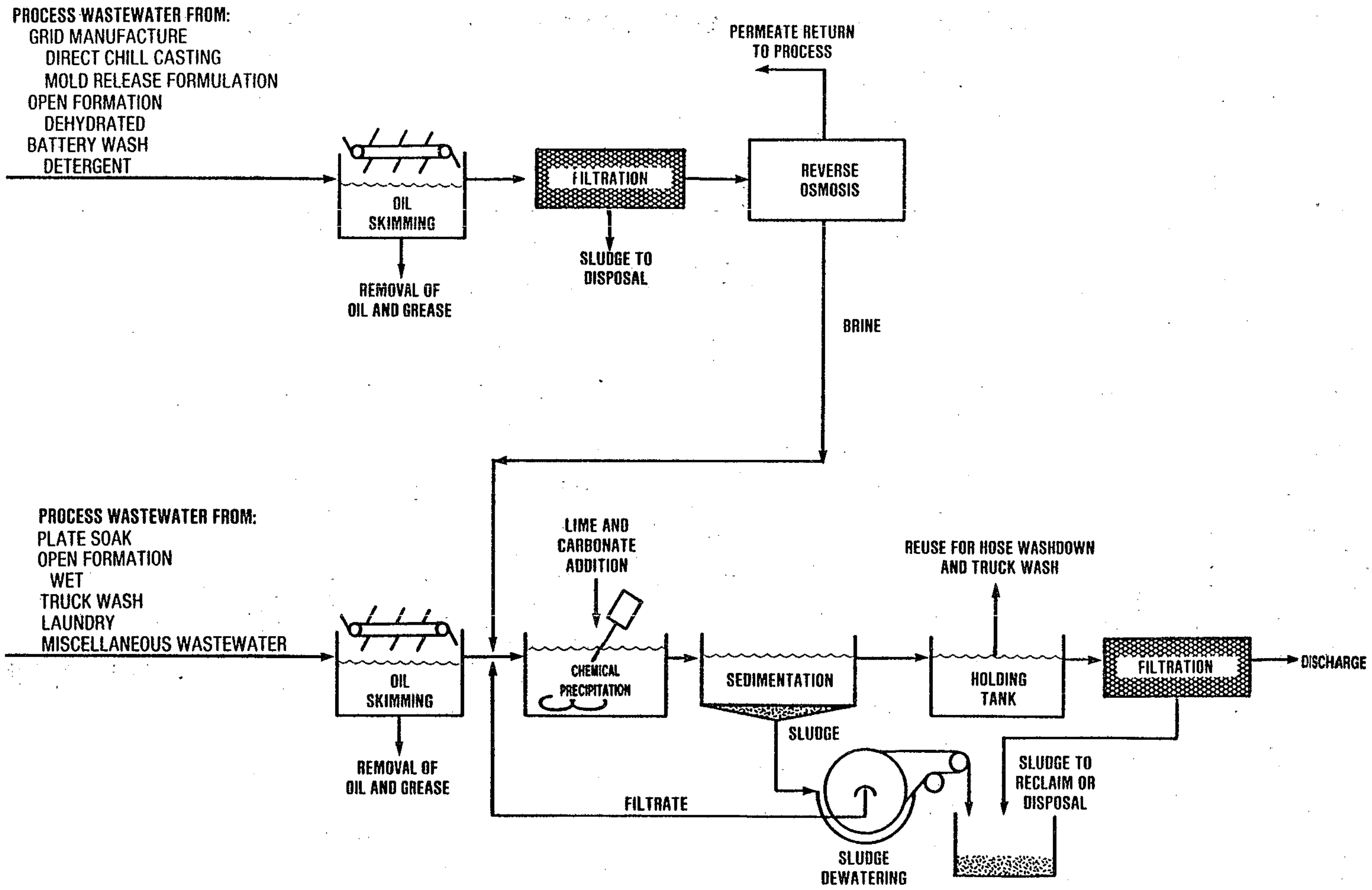
IN-PROCESS TECHNOLOGIES ARE THE SAME AS OPTION 1

FIGURE X-2. LEAD SUBCATEGORY BAT OPTION 2 TREATMENT



IN-PROCESS TECHNOLOGIES ARE THE SAME AS OPTION 1

FIGURE X-3. LEAD SUBCATEGORY BAT OPTION 3 TREATMENT



ADDITIONAL RECOMMENDED IN-PROCESS TECHNOLOGY: REUSE TREATED WATER FOR TRUCK WASH

FIGURE X-4. LEAD SUBCATEGORY BAT OPTION 4 TREATMENT

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

The basis for new source performance standards (NSPS) under Section 306 of the Clean Water Act is the best available demonstrated control technology (BDT).

This section presents effluent characteristics attainable by new sources through the application of the best available demonstrated control technology (BDT), processes, operating methods, or other alternatives including, where practicable, a standard permitting no discharge of pollutants. Five levels of technology are discussed; cost, performance and pollutant removals are presented, and the rationale for selection of the BDT is outlined. The selection of pollutant parameters for specific regulations is discussed and discharge limitations for the regulated pollutants are presented for the lead subcategory.

TECHNICAL APPROACH TO NSPS

The technology options considered as possible BDT for the lead subcategory are similar to the options considered at BAT. BAT options are discussed in outline form and in detail in Section X (pages 586-593) and are depicted schematically in Figures X-1 to X-4 (pages 616-619). These options were evaluated for their applicability, cost, and pollutant reduction benefits. Option 1 was selected as the BAT model technology.

Each of the four BAT options is considered as an option for BDT. In addition to these four options, the Agency considered another option, option 5, for BDT. Option 5 is almost identical to option 2, the only difference being that treated water is reused for truck washing activities. This results in a reduction of the truck wash regulatory flow to 0.005 l/kg. The treatment scheme for option 5 is identical to the scheme shown in Figure X-2. Both truck wash and floor wash water are recycled from the holding tank.

As discussed in Section X, EPA revised option 4 between proposal and promulgation. At proposal, option 4 consisted of oil skimming, chemical precipitation (with lime and carbonate), filtration, and reverse osmosis for all process streams. The permeate from the reverse osmosis unit was returned to the manufacturing process for use as make up water. The brine containing essentially all of the process wastewater pollutants, was treated in a system identical to the end-of-pipe system provided in option 3. This option was selected as the basis for the proposed NSPS.

Commenters on the proposed NSPS contended that reverse osmosis is not demonstrated in the subcategory and is not readily transferable from other categories or subcategories. Commenters also pointed out that reverse osmosis technology could not adequately treat all of the waste streams at a lead battery plant. They stated that the technology would be plagued by operational problems due to its sensitivity to temperature, pH, acidity, chloride concentrations and blinding. EPA agrees with the commenters that reverse osmosis may not adequately treat all lead battery wastewater discharges. However, the Agency believes that a combination of filtration and reverse osmosis for less concentrated wastewaters followed by lime, settle, and filter technology for the reverse osmosis brine and other wastewaters is an appropriate technology for option 4. Less concentrated wastewaters which may be treated by reverse osmosis include open dehydrated formation wastewater, continuous strip casting wastewater, mold release formulation equipment washdown, and detergent battery wash wastewater. This new treatment scheme is the basis for the revised option 4. The Agency carefully considered this option and has concluded that all of the technologies included as part of this option have been demonstrated in industrial situations. This technology has been used on acid mine drainage which is similar to battery manufacturing wastes in that it contains high levels of toxic metals and sulfuric acid.

The Agency has elected to base NSPS on option 5. This option adds polishing filtration to the BAT end-of-pipe treatment (chemical precipitation and sedimentation) and increased flow reduction measures. The increased flow reduction for NSPS is applied to truck washing. The BAT regulatory flow for truck washing is reduced from 0.014 l/kg (BPT and BAT) to 0.005 l/kg for NSPS. This flow reduction measure is based on using two-stage rinsing for truck washing; 1) a rinse with treated wastewater, 2) followed by a final fresh water rinses. The promulgated NSPS will result in the discharge of only a miniscule amount of pollutants from new plants. EPA has concluded that a national standard based on the use of advanced end-of-pipe treatment technologies beyond the recommended BAT plus filtration in order to remove the remaining deminimis pollutants is not warranted.

Option 5 has been selected as the preferred option because it improves pollutant removal and the technology is demonstrated. As an alternative to flow reduction and treatment, new plants can select dry manufacturing processes and water conservation practices and achieve no discharge of pollutants. No discharge of wastewater pollutants is practiced by 57 existing plants. Also, as discussed in the EIA, no entry impacts are projected with the selection of this option.

POLLUTANT REMOVALS AND COSTS

The Agency used the normal discharging plant to estimate costs and pollutant reduction benefits associated with the five BDT treatment options for a new direct discharge lead battery plant. Pollutant reduction benefits for options 1 to 4 are identical to those presented for the normal discharging plant in Table X-5 (page 603). Pollutant reduction benefits for option 5 are presented in Table XI-1 (page 624). Based on the normal discharging plant, a new direct discharger would generate 14,459 kilograms (31,810 pounds) per year of toxic pollutants. The NSPS technology (option 5) would reduce toxic pollutant levels to 4.33 kilograms (9.53 pounds) per year and the discharge of other pollutants to 42 kilograms (92.4 pounds) per year. The capital investment cost for a new model lead battery manufacturing plant to install the NSPS technology is estimated to be $0.119 million with annual costs of $0.069 million (1983).

REGULATED POLLUTANT PARAMETERS

The Agency has no reason to believe that the pollutants that will be found in significant quantities for processes within new sources will be any different than with existing sources. Consequently, pollutants selected for regulation, in accordance with the rationale of Section VI, IX, and X are the same ones that were selected at BAT with the addition of TSS, oil and grease, and pH.

NEW SOURCE PERFORMANCE STANDARDS

New source performance standards for this subcategory are based on the wastewater flow reductions achieved by improved in-process control and recycle, and the pollutant concentrations achievable by lime, settle and filter end-of-pipe treatment. Regulatory flows used as the basis for new source standards are the same as those used at BAT (with the exception of truck wash) and can be found in Table X-1 (page 598). The NSPS regulatory flow for truck wash is 0.005 l/kg. Effluent concentrations achievable by the application of new source technology are displayed in Table VII-21 (page 418).

Tables XI-2 through 10 (pages 625-633) display NSPS for the lead subcategory.

TABLE XI-1

POLLUTANT REDUCTION BENEFITS
OPTION 5

PARAMETER		RAW WASTE kg/yr	OPTION 5	
			Removed kg/yr	Discharged kg/yr
FLOW 1/yr (10^6)		69.91		2.87
114	Antimony	10.20	8.85	1.35
118	Cadmium	0.37	0.23	0.14
119	Chromium	5.30	5.10	0.20
120	Copper	12.29	11.17	1.12
122	Lead	14389.65	14389.42	0.23
123	Mercury	0.57	0.57	0.00
124	Nickel	5.09	4.46	0.63
126	Silver	1.32	1.32	0.00
128	Zinc	34.04	33.38	0.66
	Aluminum	20.82	16.54	4.28
	Iron	340.56	339.76	0.80
	Manganese	2.79	2.39	0.40
	Oil & Grease	3817.66	3788.88	28.78
	TSS	80779.35	80771.87	7.48
	Total Toxics	14458.83	14454.50	4.33
	Total Nonconv.	364.17	358.69	5.48
	Total Conv.	84597.01	84560.75	36.26
	Total Pollutants	99420.01	99373.94	46.07
	Sludge		605046	

TABLE XI-2

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Mold Release Formulation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.01	0.0052
Cadmium	0.0012	0.0005
Chromium	0.0022	0.0009
*Copper	0.0077	0.0037
*Lead	0.0017	0.0008
Mercury	0.0009	0.0004
Nickel	0.0033	0.0022
Silver	0.0017	0.0007
Zinc	0.0061	0.0025
Aluminum	0.0367	0.0163
*Iron	0.0072	0.0037
Manganese	0.0018	0.0014
*Oil and Grease	0.060	0.060
*TSS	0.090	0.072
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-3

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Direct Chill Lead Casting

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.000386	0.000172
Cadmium	0.000040	0.000016
Chromium	0.000074	0.000030
*Copper	0.000256	0.000122
*Lead	0.000056	0.000026
Mercury	0.000030	0.000012
Nickel	0.000110	0.000074
Silver	0.000058	0.000024
Zinc	0.000204	0.000084
Aluminum	0.00122	0.00054
*Iron	0.000240	0.000122
Manganese	0.00006	0.00005
*Oil and Grease	0.0020	0.0020
*TSS	0.0030	0.0024
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-4

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Open Formation - Dehydrated

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	3.24	1.44
Cadmium	0.33	0.13
Chromium	0.62	0.25
*Copper	2.15	1.02
*Lead	0.47	0.21
Mercury	0.25	0.10
Nickel	0.92	0.62
Silver	0.48	0.20
Zinc	1.71	0.70
Aluminum	10.26	4.55
*Iron	2.01	1.02
Manganese	0.50	0.39
*Oil and Grease	16.80	16.80
*TSS	25.20	20.16
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-5

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Open Formation - Wet

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.102	0.045
Cadmium	0.010	0.004
Chromium	0.019	0.007
*Copper	0.067	0.032
*Lead	0.014	0.006
Mercury	0.007	0.003
Nickel	0.029	0.019
Silver	0.015	0.006
Zinc	0.054	0.022
Aluminum	0.324	0.144
*Iron	0.063	0.032
Manganese	0.016	0.012
*Oil and Grease	0.53	0.53
*TSS	0.80	0.64
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-6

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Plate Soak

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.04	0.018
Cadmium	0.004	0.001
Chromium	0.007	0.003
*Copper	0.026	0.012
*Lead	0.005	0.002
Mercury	0.003	0.001
Nickel	0.011	0.007
Silver	0.006	0.002
Zinc	0.021	0.008
Aluminum	0.128	0.057
*Iron	0.025	0.012
Manganese	0.006	0.005
*Oil and Grease	0.21	0.21
*TSS	0.32	0.25
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-7

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Battery Wash (Detergent)

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.868	0.387
Cadmium	0.090	0.036
Chromium	0.166	0.067
*Copper	0.576	0.274
*Lead	0.126	0.058
Mercury	0.067	0.027
Nickel	0.247	0.166
Silver	0.130	0.054
Zinc	0.459	0.189
Aluminum	2.750	1.22
*Iron	0.540	0.274
Manganese	0.135	0.104
*Oil and Grease	4.50	4.50
*TSS	6.75	5.40
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-8

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Truck Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Antimony	0.009	0.004
Cadmium	0.001	0.0004
Chromium	0.001	0.000
*Copper	0.006	0.003
*Lead	0.001	0.0007
Mercury	0.0008	0.0003
Nickel	0.002	0.001
Silver	0.001	0.0006
Zinc	0.005	0.002
Aluminum	0.031	0.014
*Iron	0.006	0.003
Manganese	0.002	0.001
*Oil and Grease	0.050	0.050
*TSS	0.075	0.060
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-9

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Laundry

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.210	0.094
Cadmium	0.022	0.009
Chromium	0.040	0.016
*Copper	0.14	0.07
*Lead	0.03	0.01
Mercury	0.016	0.007
Nickel	0.060	0.040
Silver	0.032	0.013
Zinc	0.111	0.046
Aluminum	0.666	0.295
*Iron	0.13	0.07
Manganese	0.030	0.025
*Oil and Grease	1.09	1.09
*TSS	1.64	1.31
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

TABLE XI-10

LEAD SUBCATEGORY
NEW SOURCE PERFORMANCE STANDARDS

Miscellaneous Wastewater Streams

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.59	0.26
Cadmium	0.06	0.02
Chromium	0.11	0.05
*Copper	0.39	0.19
*Lead	0.085	0.039
Mercury	0.05	0.02
Nickel	0.17	0.11
Silver	0.09	0.04
Zinc	0.31	0.13
Aluminum	1.88	0.83
*Iron	0.37	0.19
Manganese	0.09	0.07
*Oil and Grease	3.07	3.07
*TSS	4.61	3.69
*pH	Within the range of 7.5 to 10.0 at all times	

*Regulated Pollutant

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 Publicly Owned Treatment Works (POTW). The Clean Water Act of 1977 adds a new dimension by requiring pretreatment for pollutants, such as toxic 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, and analogous to the best available technology for removal of toxic pollutants. (Conference Report 95-830 at 87; reprinted in Comm. on Environment and Public Works, 95th Cong., 2d Session, A Legislative History of the Clean Water Act of 1977, Vol. 3 at 272).

The general pretreatment regulations can be found at 40 CFR Part 403. See 43 FR 27736 June 26, 1978, 46 FR 9404 January 28, 1981, and 47 FR 4518 February 1, 1982. These regulations describe the Agency's overall policy for establishing and enforcing pretreatment standards for new and existing users of a POTW and delineate the responsiblilities and deadlines applicable to each part in this effort. In addition, 40 CFR Part 403, Section 403.5(b), outlines prohibited discharges which apply to all users of a POTW.

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.

DISCHARGE OF WASTEWATERS TO A POTW

There are 103 plants in the lead subcategory of the battery manufacturing category which currently discharge to a POTW. Pretreatment standards are established to ensure removal of pollutants discharged by such plants which interfere with, pass through or are otherwise incompatible with a POTW. A determination of which pollutants may pass through or be incompatible with POTW operations, and thus be subject to pretreatment standards, depends on the level of treatment employed by the POTW. In general, more pollutants will pass through a POTW employing primary treatment (usually physical separation by settling) than one which has installed secondary treatment (settling plus biological treatment).

Most POTW currently 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 pass through or interfere with the normal operations of these systems. 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 useability.

The Agency based the selection of pretreatment standards for the battery category primarily on the minimization of pass through of toxic pollutants at POTW. The Agency compared the removal rates for each toxic pollutant limited by the pretreatment options to the removal rate for that pollutant at a well operated POTW. The POTW removal rates were determined through a study conducted by the Agency at over 40 POTW and a statistical analysis of the data. (See <u>Fate of Priority Pollutants In Publicly Owned Treatment Works</u>, EPA 440/1-80-301, October, 1980; and <u>Determining National Removal Credits for Selected Pollutants for Publicly Owned Treatment Works</u>, EPA 440/82-008, September, 1982). The POTW removal rates are presented below:

Toxic Pollutant	POTW Removal Rate
Cadmium	38%
Chromium	65%
Copper	58%
Cyanide	52%
Lead	48%
Nickel	19%
Silver	66%
Zinc	65%

The study did not analyze national POTW removals for mercury. The range of removal indicated by the data ranged from 19 to 66 percent. However, as discussed in Section VI, mercury has inhibiting effects upon activated sludge POTW at levels of 0.1 mg/l and loss of COD removal efficiency of 59 percent is reported with 10.0 mg/l of mercury. Therefore, unless treated at the source, mercury is likely to cause POTW interference. The model treatment technologies chosen as the basis for PSES and PSNS will achieve removals of greater than 99.9 percent for toxic metals as is demonstrated by the pollutant reduction benefits shown in Table XII-1 (page 640).

The pretreatment options selected provide for significantly more removal of toxic pollutants than would occur if battery wastewaters were discharged untreated to the POTW. Thus, pretreatment standards will control the discharge of toxic pollutants to the POTW and prevent pass through.

TECHNICAL APPROACH TO PRETREATMENT

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 metals which pass through 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 combine both in-plant technology and wastewater treatment to reduce the mass of pollutants (especially toxic 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.

Option 0 for pretreatment standards for existing sources (PSES) is identical to BPT (option 0) which is described in Section IX. PSES options 1-4 are identical to BAT options 1-4 respectively. End-of-pipe treatment systems for each of these options are depicted in Sections IX or X as appropriate. PSNS options 1-5 are the same as BDT options 1-5 discussed in Section XI.

Effluent performance achieved by these pretreatment options will be the same as that provided by the respective BPT, BAT and BDT options and is indicated by the production normalized flow information provided in Section V and the technology performance data shown in Section VII. Compliance cost data for all options are displayed in Table X-8 (page 606). Pollutant removals for indirect dischargers of the lead subcategory are displayed in Table XII-1 (page 640).

PSES AND PSNS OPTION SELECTION

Option 1 is selected as the PSES option because standards are achievable using technologies and practices that are currently in use at plants in the subcategory. Implementation of this technology will result in a significant reduction of toxic pollutant discharges to POTW which would otherwise pass through. This option is analogous to that chosen for BAT and has been determined to be economically achievable.

Option 5 is selected as the regulatory approach for pretreatment standards for new sources (PSNS). This option is analogous to that chosen for NSPS and has been chosen for the same reasons as discussed in Section XI.

POLLUTANT REMOVAL BENEFITS AND COST

As a means of evaluating the economic achievability of each of the options, the Agency developed cost estimates for existing plants and used the normal dischargingg plant to estimate costs and benefits for a new plant. The cost estimates for existing indirect dischargers are presented in Table X-8.

Implementation of PSES will remove 1,488,399 kilograms (3,274,478 pounds) per year of toxic metals and 8,743,591 kilograms (19,235,899 pounds) per year of other pollutants from the estimated raw waste generation for indirect dischargers, at a capital cost, above equipment in place, of $7.114 million and a total annual cost of $4.069 million. These costs assume plants will install PSES treatment systems at the PSES regulatory flow. The Agency has determined that these standards are economically achievable.

New source plant costs were estimated for the lead subcategory using the normal discharging plant. The total capital investment cost for a new lead battery manufacturing plant to install PSNS technology is $0.119 million with corresponding total annual costs of $0.069 million. This new lead battery manufacturing plant would generate a raw waste load of approxiamtely 14,459 kilograms (31,810 pounds) per year of toxic pollutants and 84,961 kilograms (186,914 pounds) per year of other pollutants. Application of PSNS technology would reduce the toxic pollutant discharge to 4.33 kilograms (9.53 pounds) per year and the discharge of other pollutants to 42 kilograms (92.4 pounds) per year.

POLLUTANT PARAMETERS FOR REGULATION

Pollutant parameters selected for pretreatment regulation in this subcategory are copper and lead. As discussed in Section X these pollutants were selected for their toxicity, use within the subcategory and treatability. For the pretreatment standards, POTW treatment, incompatability and pass-through of copper and lead were also considered. Conventional pollutants and iron are not specifically regulated because a POTW may use iron as a coagulant in the treatment process and a POTW is specifically designed to treat the conventional pollutants.

PRETREATMENT STANDARDS

Effluent standards for existing pretreatment sources are identical to the BAT limitations discussed in Section X. These standards are expressed in terms of mg of pollutant per kg of production normalizing parameter for each process element. PSES are displayed in Tables XII-2 to XII-10 (pages 641-649). These standard tables list all the pollutants which were considered for regulation, and those regulated are *'d.

Pretreatment standards for new sources are identical to NSPS discussed in Section XI except that conventional pollutants and iron are not regulated. Standards are displayed in Tables XII-11 to XII-19 (pages 650-658).

TABLE XII-1

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
LEAD SUBCATEGORY - INDIRECT DISCHARGERS

PARAMETER	RAW WASTE	PSES 0		PSES 1		PSES 2		PSES 3		PSES 4	
	kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr	removed kg/yr	discharged kg/yr
FLOW 1/yr (10^6)	7200.73		2143.43		297.67		297.67		297.67		177.16
114 Antimony	1050.60	452.17	598.43	842.54	208.06	910.52	140.08	910.52	140.08	968.20	82.40
118 Cadmium	38.11	21.63	16.48	25.75	12.36	25.75	12.36	35.02	3.09	29.87	8.24
119 Chromium	545.90	366.68	179.22	521.18	24.72	525.30	20.60	522.21	23.69	534.57	11.33
120 Copper	1265.87	194.67	1071.20	1004.25	261.62	1150.51	115.36	1251.45	14.42	1197.89	67.98
122 Lead	1482133.95	1481877.48	256.47	1482098.93	35.02	1482110.26	23.69	1482130.86	3.09	1482120.56	13.39
123 Mercury	58.71	4.12	54.59	58.71	0.00	58.71	0.00	58.71	0.00	58.71	0.00
124 Nickel	524.27	18.54	505.73	303.85	220.42	459.38	64.89	509.85	14.42	486.16	38.11
126 Silver	135.96	135.96	0.00	135.96	0.00	135.96	0.00	135.96	0.00	135.96	0.00
128 Zinc	3506.12	2799.54	706.58	3408.27	97.85	3438.14	67.98	3503.03	3.09	3465.95	40.17
Aluminum	2144.46	684.95	1459.51	1477.02	667.44	1700.53	443.93	1700.53	443.93	1881.81	262.65
Iron	35077.68	34199.09	878.59	34956.14	121.54	34994.25	83.43	34994.25	83.43	35029.27	48.41
Manganese	287.37	23.69	263.68	225.57	61.80	246.17	41.20	246.17	41.20	263.68	23.69
Oil & Grease	393218.98	371783.65	21435.33	390237.13	2981.85	390237.13	2981.85	390237.13	2981.85	391454.59	1764.39
TSS	8320273.05	8294549.83	25723.22	8316694.83	3578.22	8319498.49	774.56	8319498.49	774.56	8319814.70	458.35
Total Toxics	1489259.49	1485870.79	3388.70	1488399.44	860.05	1488814.53	444.96	1489057.61	201.88	1488997.87	261.62
Total Nonconv.	37509.51	34907.73	2601.78	36658.73	850.78	36940.95	568.56	36940.95	568.56	37174.76	334.75
Total Conv.	8713492.03	8666333.48	47158.55	8706931.96	6560.07	8709735.62	3756.41	8709735.62	3756.41	8711269.29	2222.74
Total Pollu.	10240261.03	10187112.00	53149.03	10231990.13	8270.90	10235491.10	4769.93	10235734.18	4526.85	10237441.92	2819.11
Sludge kg/yr		62020523		62290177		62319532		62323034		62335600	

TABLE XII-2

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Mold Release Formulation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.01	0.008
Cadmium	0.002	0.0009
Chromium	0.003	0.001
*Copper	0.011	0.006
*Lead	0.002	0.001
Mercury	0.002	0.0006
Nickel	0.01	0.008
Silver	0.0025	0.0010
Zinc	0.009	0.004
Aluminum	0.04	0.02
Iron	0.007	0.003
Manganese	0.004	0.002

*Regulated Pollutant

TABLE XII-3

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Direct Chill Lead Casting

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used		
Antimony	0.00057	0.00026
Cadmium	0.00007	0.00003
Chromium	0.00009	0.00004
*Copper	0.0004	0.0002
*Lead	0.00008	0.00004
Mercury	0.00005	0.00002
Nickel	0.00038	0.00025
Silver	0.00008	0.00003
Zinc	0.00029	0.00012
Aluminum	0.0013	0.0006
Iron	0.0002	0.0001
Manganese	0.0001	0.0006

*Regulated Pollutant

TABLE XII-4

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Open Formation - Dehydrated

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	4.82	2.15
Cadmium	0.57	0.25
Chromium	0.73	0.30
*Copper	3.19	1.68
*Lead	0.71	0.34
Mercury	0.42	0.16
Nickel	3.22	2.13
Silver	0.68	0.28
Zinc	2.45	1.02
Aluminum	10.80	5.38
Iron	2.02	1.02
Manganese	1.14	0.49

*Regulated Pollutant

TABLE XII-5

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Open Formation - Wet

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.152	0.067
Cadmium	0.018	0.007
Chromium	0.023	0.009
*Copper	0.100	0.053
*Lead	0.022	0.010
Mercury	0.013	0.005
Nickel	0.101	0.067
Silver	0.021	0.009
Zinc	0.077	0.032
Aluminum	0.34	0.17
Iron	0.06	0.03
Manganese	0.04	0.02

*Regulated Pollutant

TABLE XII-6

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Plate Soak

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.060	0.026
Cadmium	0.007	0.003
Chromium	0.009	0.003
*Copper	0.039	0.021
*Lead	0.008	0.004
Mercury	0.005	0.002
Nickel	0.040	0.026
Silver	0.008	0.003
Zinc	0.030	0.012
Aluminum	0.135	0.067
Iron	0.030	0.010
Manganese	0.014	0.006

*Regulated Pollutant

TABLE XII-7

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Battery Wash (Detergent)

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	1.29	0.58
Cadmium	0.15	0.07
Chromium	0.20	0.08
*Copper	0.86	0.45
*Lead	0.19	0.09
Mercury	0.11	0.05
Nickel	0.86	0.57
Silver	0.18	0.08
Zinc	0.66	0.27
Aluminum	2.89	1.44
Iron	0.54	0.27
Manganese	0.31	0.13

*Regulated Pollutant

TABLE XII-8

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Truck Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Antimony	0.040	0.017
Cadmium	0.004	0.002
Chromium	0.006	0.002
*Copper	0.026	0.014
*Lead	0.005	0.002
Mercury	0.003	0.001
Nickel	0.026	0.017
Silver	0.005	0.002
Zinc	0.020	0.008
Aluminum	0.09	0.04
Iron	0.016	0.008
Manganese	0.01	0.004

*Regulated Pollutant

TABLE XII-9

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Laundry

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.31	0.14
Cadmium	0.037	0.016
Chromium	0.05	0.02
*Copper	0.21	0.11
*Lead	0.05	0.02
Mercury	0.027	0.011
Nickel	0.209	0.138
Silver	0.045	0.019
Zinc	0.16	0.07
Aluminum	0.70	0.35
Iron	0.13	0.07
Manganese	0.07	0.03

*Regulated Pollutant

TABLE XII-10

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR EXISTING SOURCES

Miscellaneous Wastewater Streams

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.88	0.39
Cadmium	0.10	0.05
Chromium	0.14	0.06
*Copper	0.58	0.31
*Lead	0.13	0.06
Mercury	0.08	0.03
Nickel	0.59	0.39
Silver	0.13	0.05
Zinc	0.45	0.19
Aluminum	1.97	0.98
Iron	0.37	0.19
Manganese	0.21	0.09

*Regulated Pollutant

TABLE XII-11

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Mold Release Formulation

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.01	0.0052
Cadmium	0.0012	0.0005
Chromium	0.0022	0.0009
*Copper	0.0077	0.0037
*Lead	0.0017	0.0008
Mercury	0.0009	0.0004
Nickel	0.0033	0.0022
Silver	0.0017	0.0007
Zinc	0.0061	0.0025
Aluminum	0.0367	0.0163
Iron	0.0072	0.0037
Manganese	0.0018	0.0014

*Regulated Pollutant

TABLE XII-12

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Direct Chill Lead Casting

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.000386	0.000172
Cadmium	0.000040	0.000016
Chromium	0.000074	0.000030
*Copper	0.000256	0.000122
*Lead	0.000056	0.000026
Mercury	0.000030	0.000012
Nickel	0.000110	0.000074
Silver	0.000058	0.000024
Zinc	0.000204	0.000084
Aluminum	0.00122	0.00054
Iron	0.000240	0.000122
Manganese	0.00006	0.00005

*Regulated Pollutant

TABLE XII-13

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Open Formation - Dehydrated

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	3.24	1.44
Cadmium	0.33	0.13
Chromium	0.62	0.25
*Copper	2.15	1.02
*Lead	0.47	0.21
Mercury	0.25	0.10
Nickel	0.92	0.62
Silver	0.48	0.20
Zinc	1.71	0.70
Aluminum	10.26	4.55
Iron	2.01	1.02
Manganese	0.50	0.39

*Regulated Pollutant

TABLE XII-14

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Open Formation - Wet

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.102	0.045
Cadmium	0.010	0.004
Chromium	0.019	0.007
*Copper	0.067	0.032
*Lead	0.014	0.006
Mercury	0.007	0.003
Nickel	0.029	0.019
Silver	0.015	0.006
Zinc	0.054	0.022
Aluminum	0.324	0.144
Iron	0.063	0.032
Manganese	0.016	0.012

*Regulated Pollutant

TABLE XII-15

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Plate Soak

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.04	0.018
Cadmium	0.004	0.001
Chromium	0.007	0.003
*Copper	0.026	0.012
*Lead	0.005	0.002
Mercury	0.003	0.001
Nickel	0.011	0.007
Silver	0.006	0.002
Zinc	0.021	0.008
Aluminum	0.128	0.057
Iron	0.025	0.012
Manganese	0.006	0.005

*Regulated Pollutant

TABLE XII-16

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Battery Wash (Detergent)

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.868	0.387
Cadmium	0.090	0.036
Chromium	0.166	0.067
*Copper	0.576	0.274
*Lead	0.126	0.058
Mercury	0.067	0.027
Nickel	0.247	0.166
Silver	0.130	0.054
Zinc	0.459	0.189
Aluminum	2.750	1.22
Iron	0.540	0.274
Manganese	0.135	0.104

*Regulated Pollutant

TABLE XII-17

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Truck Wash

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
Metric Units - mg/kg of lead in trucked batteries English Units - lb/1,000,000 lb of lead in trucked batteries		
Antimony	0.009	0.004
Cadmium	0.001	0.0004
Chromium	0.001	0.000
*Copper	0.006	0.003
*Lead	0.001	0.0007
Mercury	0.0008	0.0003
Nickel	0.002	0.001
Silver	0.001	0.0006
Zinc	0.005	0.002
Aluminum	0.031	0.014
Iron	0.006	0.003
Manganese	0.002	0.001

*Regulated Pollutant

TABLE XII-18

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Laundry

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.210	0.094
Cadmium	0.022	0.009
Chromium	0.040	0.016
*Copper	0.14	0.07
*Lead	0.03	0.01
Mercury	0.016	0.007
Nickel	0.060	0.040
Silver	0.032	0.013
Zinc	0.111	0.046
Aluminum	0.666	0.295
Iron	0.13	0.07
Manganese	0.030	0.025

*Regulated Pollutant

TABLE XII-19

LEAD SUBCATEGORY
PRETREATMENT STANDARDS FOR NEW SOURCES

Miscellaneous Wastewater Streams

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	Metric Units - mg/kg of lead used English Units - lb/1,000,000 lb of lead used	
Antimony	0.59	0.26
Cadmium	0.06	0.02
Chromium	0.11	0.05
*Copper	0.39	0.19
*Lead	0.085	0.039
Mercury	0.05	0.02
Nickel	0.17	0.11
Silver	0.09	0.04
Zinc	0.31	0.13
Aluminum	1.88	0.83
Iron	0.37	0.19
Manganese	0.09	0.07

*Regulated Pollutant

SECTION XIII

BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 amendments to the Clean Water Act added Section 301(b)(2)(E), establishing "best conventional pollutant control technology" (BCT) for discharge of conventional pollutants from existing industrial point sources. Conventional pollutants are those defined in Section 304(a)(4) [biological oxygen-demanding pollutants (BOD5), total suspended solids (TSS), fecal coliform, and pH] and any additional pollutants defined by the Administrator as "conventional" [oil and grease (O&G) 44 FR 44501, July 30, 1979].

BCT is not an additional limitation but replaces BAT for the control of conventional pollutants. In addition to other factors specified in Section 304(b)(4)(B), the Act requires that BCT Limitations be assessed in light of a two part "cost-reasonableness" test (American Paper Institute v. EPA, 660 F.2d 954 (4th Cir. 1981)). The first test compares the cost for private industry to reduce its conventional pollutants with the costs to publicly owned treatment works for similar levels of reduction in their discharge of these pollutants. The second test examines the cost-effectiveness of additional industrial treatment beyond BPT. EPA must find that limitations are "reasonable" under both tests before establishing them as BCT. In no case may BCT be less stringent than BPT.

EPA published its methodology for carrying out the BCT analysis on August 29, 1979 (44 FR 50732). In the case mentioned above, the Court of Appeals ordered EPA to correct data errors underlying EPA's calculation of the first test, and to apply the second cost test. (EPA argued that a second cost was not required.) On October 29, 1982, the Agency proposed a revised BCT methodology. EPA is deferring proposal of BCT limitations for the battery manufacturing category until the proposed methodology is made final.

SECTION XIV

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SECTION XV

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SECTION XVI

GLOSSARY

Active Material - Electrode material that reacts chemically to produce electrical energy when a cell discharges. Also, such material in its original composition, as applied to make an electrode.

Air Scrubbing - 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 a zinc anode with mercury to prevent internal corrosion and resultant gassing in a cell. (2) Treatment of wastewater 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 (a mixture of lead and lead oxide called leady oxide) 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 wastewater to (1) effect a more uniform distribution of velocities or (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 (a mixture of lead and lead oxide called leady oxide) for lead acid batteries.

Barton Pot - A reactor vessel, used in the Barton process, into which molten lead is fed and vigorously agitated to form fine lead droplets in the presence of air. The resulting mixture of unoxidized lead and lead oxides (leady oxide) comprises an active material in lead acid batteries.

Batch Treatment - A waste treatment method where wastewater is collected over a period of time and then treated before discharge, often in the same vessel in which it is collected.

Battery - A device that transforms chemical energy into electrical energy. This term usually applies to two or more cells connected in series, parallel or a combination of both. Common usage has blurred the distinction between the terms "cell" and "battery" 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 automotive batteries.

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.

Burn - Connection of terminals, posts, or connectors in a lead acid battery by welding.

Button Cell - A tiny, circular battery, any of several types, made for a watch or for other microelectronic applications.

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 pouring molten lead into molds and allowing solidification.

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 wastewater.

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 used in its own container as a single cell battery or be combined and interconnected with other cells in a container to form a multicelled battery.

Central Treatment Facility - Treatment plant which co-treats process wastewaters from more than one manufacturing operation or co-treats process wastewaters with noncontact cooling water, or with nonprocess wastewaters (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 wastewater sludge.

Charge - The conversion of electrical energy into chemical energy within a cell-battery. This restoration of active electronic materials is done by forcing a current through the cell-battery in the opposite direction to that during discharge. See "Formation."

Chemical Coagulation - The destablization and initial aggregation of colloidal and finely divided suspended matter by the action of a floc-forming chemical.

Chemical Oxygen Demand (COD) - (1) A test based on the fact that 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 inability to differentiate between biologically oxidizable and biologically inert organic matter. The major advantage of this test is the short time required for evaluation (2 hrs). (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 metals from wastewater.

Chemical Treatment - Treating contaminated water by chemical means.

Clarifier - A unit which provides settling and removal of solids from wastewater.

Closed Formation - Formation of lead battery plates done with the plates already in the battery case.

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 Wastewater Sample - A combination of individual samples of water or wastewater taken at selected intervals and mixed in proportion to flow or time to minimize the effect of stream variability.

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, wastewaters, or sludge by means of an approved scavenger service.

Cooling Tower - A device used to remove heat from cooling water used in the manufacturing processes before returning the water for recycle or reuse.

Countercurrent Cascade Rinsing - A method of rinsing or washing using a segmented tank system in which water flows from one tank segment to the next counter to the direction of movement of the material being washed.

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 waters of the U.S. 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 wastewater 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 drained or 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. Also referred to as dehydrated plate or dehydrated batteries.

Drying Beds - Areas for dewatering of sludge by evaporation and seepage.

Effluent - Industrial wastewater 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 - Electrochemical deposition of an active material from solution onto an electrode grid or plaque.

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 or removal of pollutants by treatment just prior to actual discharge to a point outside an industrial plant.

Equalization - The collection of waste streams from different sources, which vary in pH, chemical constituents, and flow rates in a common container. The effluent stream from this equalization tank has a fairly constant flow and pH level, and will contain a homogeneous chemical mixture. This tank helps to prevent an unnecessary shock to the waste treatment system.

Evaporation Ponds - A pond, usually lined, for disposal of wastewater 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 wastewater 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 rotating cylindrical drum mounted on a horizontal axis, covered with a filter cloth partially submerged in a liquid. A vacuum is maintained under the cloth for the larger part of a revolution to extract moisture. Solids collected on the surface of the filter cloth are continuously scraped off.

Filtrate - Liquid that has passed through a filter.

Filtration - Removal of solid particles from liquid or particles from air or gas stream through a permeable membrane or deep bed. The filter types include: gravity, pressure, microstraining, ultrafiltration, reverse osmosis (hyperfiltration).

Float Gauge - A device for measuring the elevation of a liquid surface, the actuating element of which is a buoyant float that rests on the liquid surface 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 wastewater 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 Wastewater 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 interchangeably 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 wastewater taken without a set time or at a set flow.

Grease - In wastewater, 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 wastewater in a tank.

Grid - The support for the active materials and a means to conduct 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 calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides, and nitrates that cause curdling of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste. It may be determined by a standard laboratory procedure or computed from the amounts of calcium and magnesium as well as iron, aluminum, manganese, barium, strontium, and zinc, and is expressed as equivalent calcium carbonate.

Heavy Metals - A general name given to the ions of metallic elements such as copper, zinc, chromium, and nickel. They are normally removed from wastewater by forming an insoluble precipitate (usually a metallic hydroxide).

Holding Tank - A tank for accumulating wastewater 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 - Method 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 - Wastewater 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 nitrogen.

Lagoon - A man-made pond or lake for holding wastewater for the removal of suspended solids. Lagoons are also used as retention ponds after chemical clarification 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 - Land area used for controlled burial of solid wastes, sludges, ashes, industrial wastes, construction wastes, or demonition wastes. Solid wastes are garbage, refuse, and other discarded material including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities.

Leaching - The solubilizing of pollutants by the action of a percolating liquid, such as water, seeping through a landfill, which potentially contaminates ground water.

Leady Oxide - Active material used for manufacture of lead-acid battery plates consisting of a mixture of lead oxides and finely divided elemental lead.

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 or 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 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) - This federal mechanism for regulating point source discharge by means of permits.

Neutralization - Chemical addition of either acid or base to a solution to adjust the pH 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.

Open Formation - Formation of lead battery plates done with the plates in open tanks of sulfuric acid. Following formation plates are placed in the battery cases.

Outfall - The point or location where wastewater discharge 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 to facilitate 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 wastewater 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 constituents of wastewater determined to be detrimental to the public health or the environment and, therefore, requiring control.

Polyelectrolytes - Materials used as a coagulant or a coagulant aid in water and wastewater 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 wastewater treatment process used to partially reduce pollution load before the wastewater 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 wastewater is passed in a treatment works.

Primary Treatment - A process to remove substantially all floating and settleable solids in wastewater and partially reduce the concentration of suspended solids.

Priority Pollutant - Any one of 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 Wastewater - 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.

Raw Water - Plant intake water prior to any treatment or use.

Recycled Water - Process wastewater or treatment facility effluent which is recirculated to the same process.

Reduction - 1. A chemical process in which the positive valence of species is decreased. 2. Wastewater 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 wastewater or treatment facility effluent which is further used in a different manufacturing process. For example, the reuse of process wash water as non-contact cooling water.

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 mercury-zinc battery; also refers to the mercury-zinc battery.

Sand Filtration - A process of filtering wastewater 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 - Wastewater 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 Wastewater Treatment - The treatment of wastewater by biological methods after primary treatment by sedimentation.

Sedimentation - The gravity induced deposition of suspended matter carried by water, wastwater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of 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 of operation; i.e., make-up water.

Settling Ponds - A large shallow body of water into which industrial wastewaters are discharged. Suspended solids settle from the wastewaters due to the long retention time of the water in the pond.

Settleable Solids (1) That matter in wastewater 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 in 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 an elevated temperature below its melting point which 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 wastewater until removed, while the liquid discharges continuously under certain wall or scum boards.

Sludge - A suspension, slurry, or solids matter produced in a waste treatment process.

Sludge Conditioning - A process employed to 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 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 closets equivalent pollutant.

Sponge - A highly porous metal powder.

Stabilization Lagoon - A shallow pond for storage of wastewater before discharge. Such lagoons may serve only to detain and equalize wastewater composition before regulated discharge to a stream, but often they are used for biological oxidation.

Stabilization Pond - A type of oxidation pond in which biological oxidation of organic matter is effected by natural or artificially 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 wastewater at the lowest point of circulating or drainage system.

Suspended Solid - (1) Solids that are in suspension in water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as 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 in slurries or suspensions are increased by gravity settling and mechanical separation of the phases, or by floatation 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 amenable to chlorination according to standard analytical methods.

Total Solids - The total amount of solids in wastewater including both dissolved and suspended solids.

Toxicity - The ability of a substance to cause injury to an organism through chemical activity.

Treatment Efficiency - Usually refers to the percentage reduction of a specific pollutant or group of pollutants by a specific wastewater treatment step or treatment plant.

Treatment Facility Effluent - Treated process wastewater.

Turbidity - (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

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 or water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening.

<u>Wet Charge Process</u> - A process for the manufacture of lead acid storage batteries in which the plates are formed by electrolysis in sulfuric acid. The plate forming process is usually done with the plates inside the assembled battery case but may be done with the plates in open tanks. In the case of large industrial wet lead acid batteries, problems in formation associated with inhomogeneities in the large plates are alleviated by open tank formation. Wet charge process batteries are shipped with acid electrolyte inside the battery casing.

<u>Wet Shelf Life</u> - The period of time that a secondary battery can stand in the charged condition before total degradation.

<u>Wet Scrubber</u> - A unit in which dust and fumes are removed from an air or gas stream to a liquid. Gas-liquid contact is promoted by jets, sprays, bubble chambers, etc.

METRIC UNITS

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by	TO OBTAIN (METRIC UNITS)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/ pound	BTU/lb	0.555	kg cal/kg	kilogram calories/ kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeter
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	3785	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 kilogram)
yard	yd	0.9144	m	meter

*Actual conversion, not a multiplier.

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